Sky and TELESCOPE

In This Issue:

A Merger of Solar Research Activities

The Founder of Relativity

Why Should an Astronomer Study Relativity?

Globular Clusters and Their History

Counting Photons—One by One

American Astronomers Report

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Vol. XIV, No. 8

JUNE, 1955

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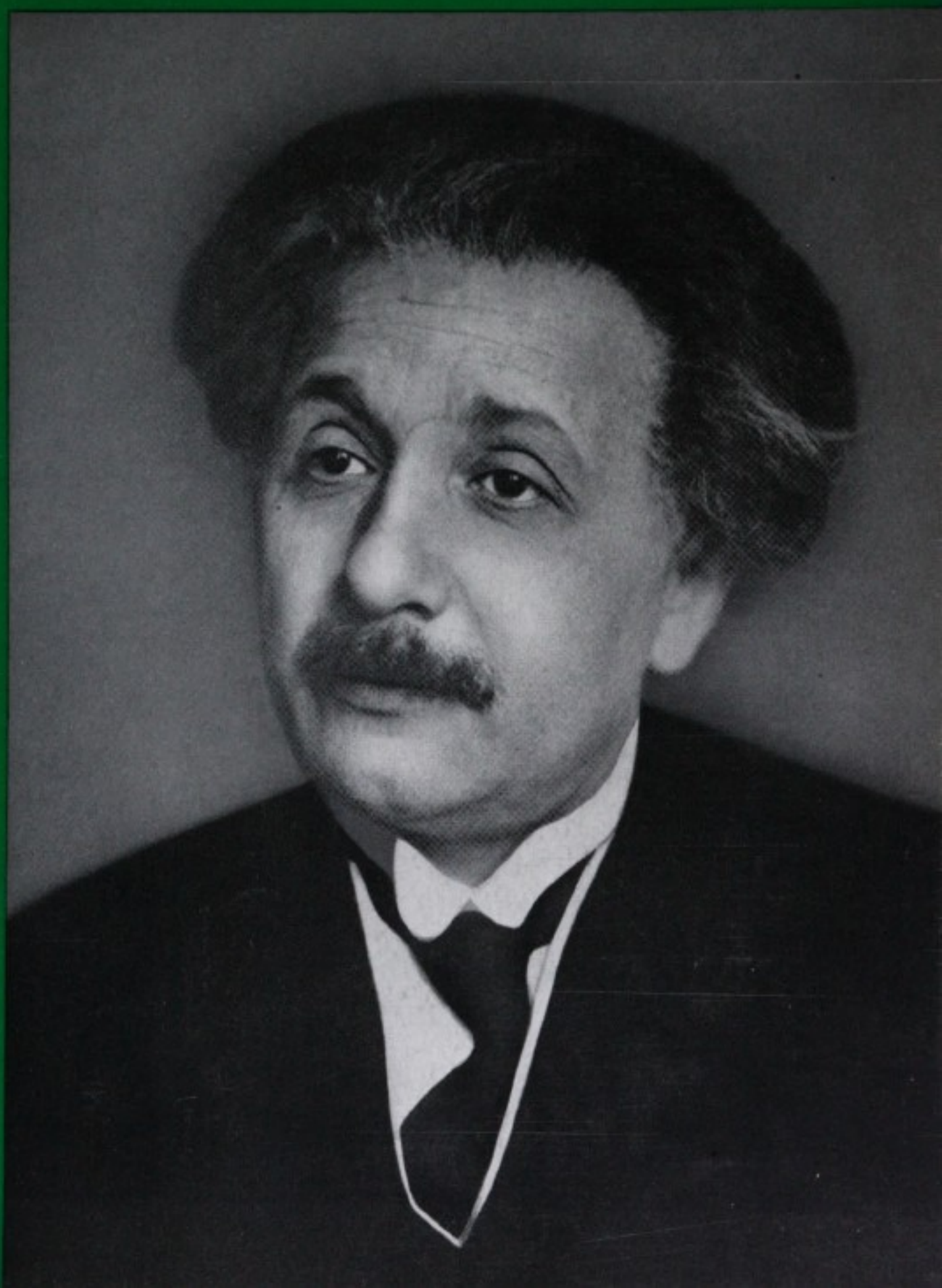

Albert Einstein
(1879-1955)

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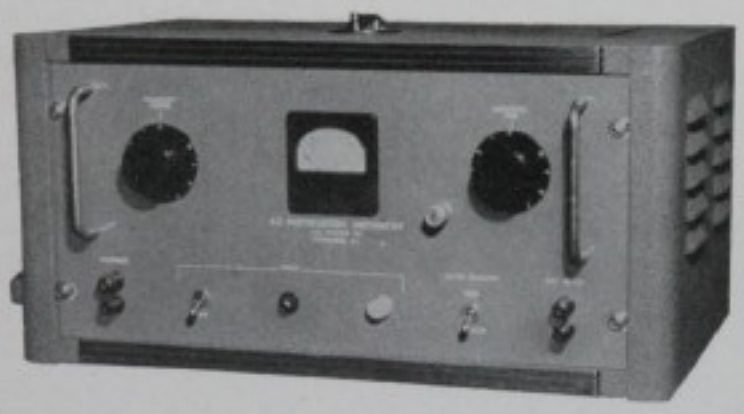

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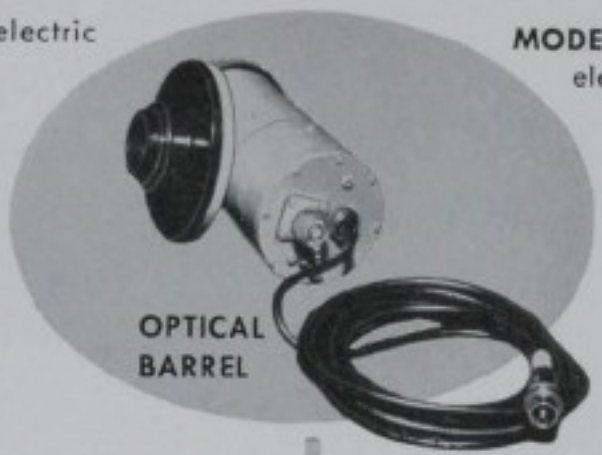

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Sky and TELESCOPE

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FEATURE PICTURE: The globular star cluster Messier 13, NGC 6205, in Hercules, photographed with the 200-inch Hale telescope. A chart showing some stars for which magnitudes are known is on page 334. Mount Wilson and Palomar Observatories photograph. (See page 326.) ..... Center

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A Merger of Solar Research Activities

CLOSE ASSOCIATION of two observatories prominent in the study of the sun and its effects on the earth will become effective next month. Harvard University and the Smithsonian Institution have formalized an agreement that should strengthen and enlarge the research programs of their respective observatories in the field of solar astrophysics.

On July 1st, Dr. Fred L. Whipple, the present chairman of the department of astronomy at Harvard, will become director of the Astrophysical Observatory of the Smithsonian Institution. He succeeds Loyal B. Aldrich, who has held that position since 1945.

The headquarters of the research work of the Astrophysical Observatory will be located in close proximity to the Harvard Observatory in Cambridge, Mass. The two observatories will make their facilities available to each other, and it is planned to have joint appointments of astronomers to their staffs.

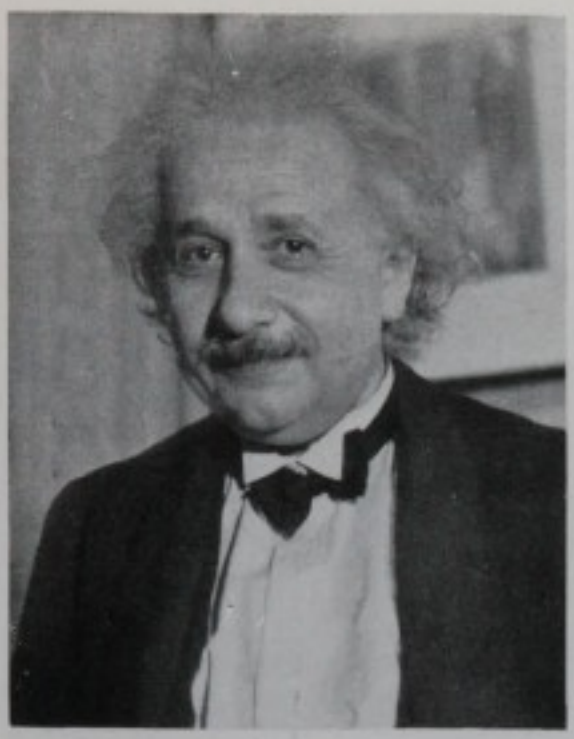
Harvard Observatory and the Smithsonian Institution are of about the same age. The former was founded in 1843, and the latter three years later, by James Smithson, whose purpose was "the increase and diffusion of knowledge among men." The enormous practical importance of the sun's light and heat led to the establishment in 1890 of the Smithsonian Astrophysical Observatory.

Its first director was Dr. Samuel P. Langley, well known both for his investigations of the infrared spectrum of the sun and for his pioneering work on heavier-than-air flight. Under his successor, Dr. Charles G. Abbot, who served from 1907 to 1944, measurement of the solar constant was begun. Two of the mountain stations established by Dr. Abbot have been in continuous operation since 1925: Montezuma, in northern Chile, and Table Mountain in the Mojave Desert of southern California. Daily measurements of the heating effect of the sun's rays have been carried on decade after decade, in order to detect changes in the solar constant and to correlate these with meteorological phenomena.

With the passage of the years, the scope of solar research has broadened enormously. The study of the sun's atmosphere and its changes has in itself become a major branch of astronomy, particularly under Dr. Donald H. Menzel, director of Harvard Observatory. His work led to the establishment of the powerful coronagraph stations at Climax,

(Continued on page 317)

The Founder of Relativity



Albert Einstein at Carnegie Hall, New York, in 1934. Photo by Clyde Fisher.

ON APRIL 18th, Albert Einstein died in his sleep at the age of 76. This was the passing of a man who had contributed more to the deep foundations of physics and astronomy than anyone else since the days of Newton. During more than 50 years of work at Zurich, Prague, Berlin, and after 1933 at the Institute for Advanced Study at Princeton, Albert Einstein's original genius illuminated both the exceedingly small and the exceedingly large. Our understanding of the atomic nucleus and the realm of the galaxies depends to a considerable extent on his work on relativity and quantum theory.

Relativity has become part of the living body of science and will remain permanently recognized, but the personality of the man who formulated it will be harder to recapture as the years intervene. What we can now gather of the impression that he made on his associates is of special value.

One of those who knew Einstein best is Professor Philipp Frank, lecturer emeritus in physics and mathematics at Harvard University, who wrote a biography of Einstein and was a friend of his since 1910. Dr. Frank occupied the chair of theoretical physics at Prague University for 26 years, where he was Einstein's successor.

On the day of Einstein's death, Dr. Frank was interviewed by Louis Lyons over radio station WGBH-FM, operated by the Lowell Institute Co-operative Broadcasting Council of Boston. The remainder of this article is based on Dr. Frank's remarks over the air at that time.

Einstein often said he was basically interested in philosophy, Dr. Frank recalls, and regarded physics as a part of philosophy. He felt that an interest in philosophy made one a better scientist by turning attention to the really basic problems involved in our investigation of nature. Einstein habitually tried to develop his ideas in a very general way. The release of atomic energy first occurred to him as an abstract logical consequence arising from the principle of relativity; this led to the conclusion that it would be possible to change matter into energy, as expressed by the famous formula, $E = mc^2$.

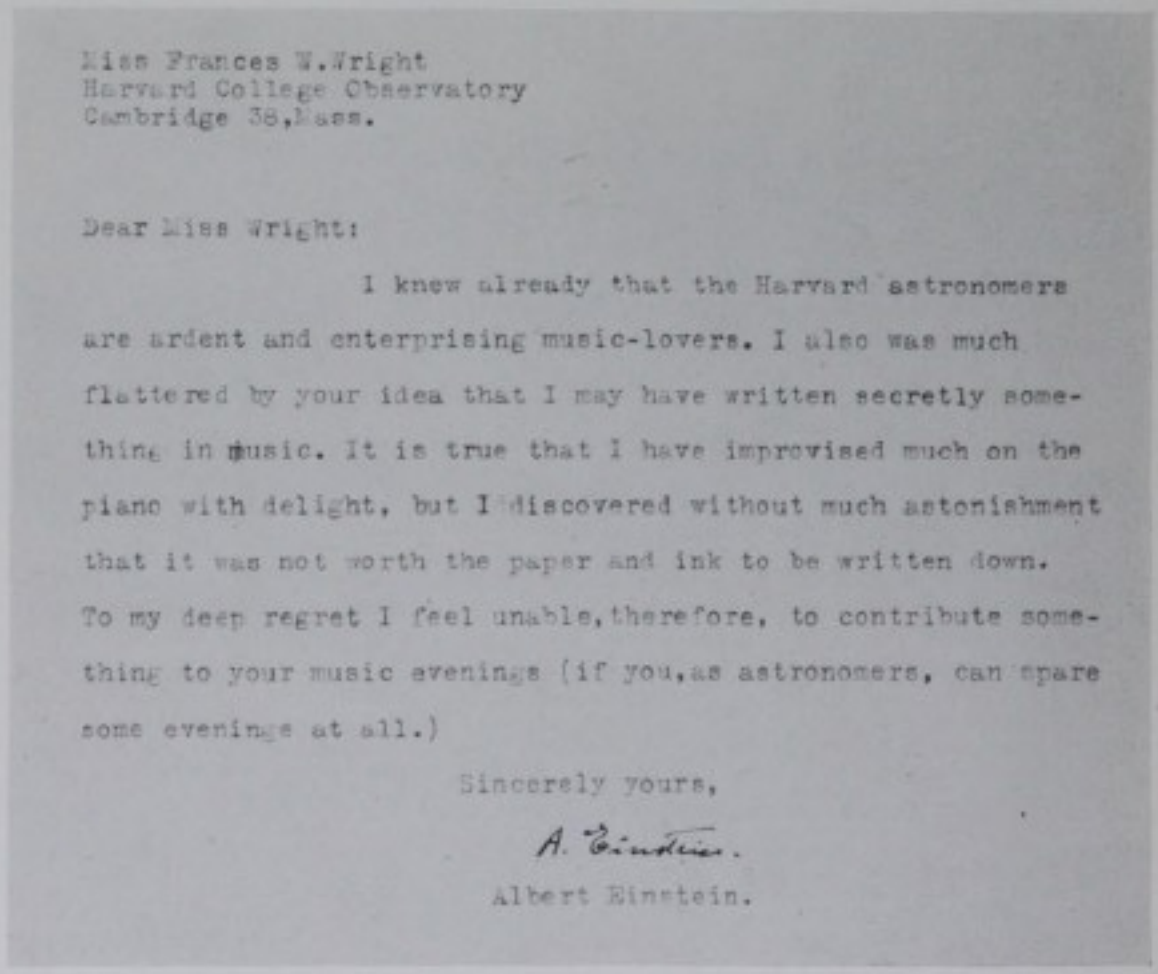
In his later years he was much occupied with seeking a general law that would be valid for all the "forces" of nature, gravitational, electrical, magnetic, nuclear, and so on. This would be the peak of all physical science, but the effort was not completely successful and when he died he was still working on unsolved problems. Those who came to speak to him about relativity found that he wanted instead to talk about further problems.

The feature of Einstein's thinking that set him above his contemporaries was his unsurpassed ability to trace *all* the consequences of an idea. For instance, he might ask a student in the laboratory for details of an experiment. On being told, he would immediately be able to express all the inferences to be drawn from the results of the experiment. This ability was of special value to his students and to scientists in general, because he could understand all the consequences that would come out of their research. To him, in return, their work was of interest because all scientific activity and experimentation were associated parts of the general pattern of thought.

Einstein did much of his work on relativity before he was 26, the age at which he announced his discovery of the special theory. Like many others in the mathematical sciences, he made fine contributions in his early years. This, Dr. Frank points out, is because mathematical creativeness is based upon intellectual ability rather than on experience. There are frequent child prodigies in mathematics and music, but not in such fields as history.

Since his early years, he had always been interested in freedom of the mind and was against all oppression. As a small child he used to be frightened at the passing of a military parade. He never liked the idea of man becoming an automaton.

He preferred to work as an individual. The greatest ideas are due to individuals; applications of science are today mostly the result of teamwork by groups of scientists working together. Einstein had a certain antipathy to being paid for research, thinking that a paid scientist might feel pressed to produce results that would not be his best work. We have



Miss Frances W.Wright
Harvard College Observatory
Cambridge 38,Mass.

Dear Miss Wright:

I knew already that the Harvard astronomers are ardent and enterprising music-lovers. I also was much flattered by your idea that I may have written secretly something in music. It is true that I have improvised much on the piano with delight, but I discovered without much astonishment that it was not worth the paper and ink to be written down. To my deep regret I feel unable, therefore, to contribute something to your music evenings (if you, as astronomers, can spare some evenings at all.)

Sincerely yours,

A. Einstein.

Albert Einstein.

Einstein's interest in music is well known. According to Dr. Frank, he preferred the earlier classics of Bach, Mozart, and Scarlatti. This letter, written January 12, 1954, was in response to an inquiry from Miss Frances W. Wright, coordinator of the group of amateur musicians at Harvard Observatory.

Dr. Einstein had his office in Fuld Hall of the Institute for Advanced Study. Here he is seen on his way home from work accompanied by the mathematician, Dr. Kurt Goedel. This picture was taken on April 7th this year, by Percy W. Witherell, of the American Association of Variable Star Observers.

his oft-quoted statement to the effect that he would rather earn his living with his hands, at a plumber's or shoemaker's job, and do his thinking on his own time. When his first great work was being done, he was employed in the Swiss patent office.

Einstein's mind was his laboratory, but his thoughts were creative rather than routine. While he was working all the time, he was always free for the problems of others who were interested in similar things. When he came to Prague Dr. Frank asked the students about his predecessor. Einstein was completely different from the other professors, the students said. Most of the teachers would tell the students to see them only in office hours, but Einstein said he had no office hours: "You can consult me any hour of the day. I am always working on my ideas, day and night. When you come, you interrupt me just a little and then I continue, so it doesn't make any difference when you interrupt."

From his interest in the thought of others came a special type of kindness that people felt. Yet he was more interested in social problems, in making life better for great numbers of people, than in the personal troubles of individuals. While it was, therefore, not easy to become his close friend, he enjoyed behaving as an ordinary citizen and talking with simple people rather than with dignitaries.

When he first visited New York in the '20's, he was already at the peak of his fame. Reporters came on board ship and asked him to explain the theory of relativity in a few sentences. Einstein said that if the words themselves were not taken too seriously, he would suggest the following:

"Before the theory of relativity, people believed that if all material bodies were to disappear from the universe, men and stones and everything, then none the less time and space would still exist. But relativity theory says that this is not true. If all material objects were to disappear, time and space would disappear too, and that is the essence of relativity."

A MERGER OF SOLAR RESEARCH ACTIVITIES

(Continued from page 315)

Colo., and Sacramento Peak, N. M., facilities that may now become available to Smithsonian scientists and observers.

Concerning the increased importance of these studies, Dr. Menzel said:

"Our work at Harvard in solar astrophysics and in meteors has already brought us into problems of the upper atmosphere and the broad realm of astronomical geophysics. This new cross-field of study is important and exciting, and we are training scientists for work in it. The demand for such scientists is great, in the government, in universities, and in industry. On theoretical lines, our studies in aerodynamics have multiple application in fields ranging from pure astrophysics to the design of airplanes or the calculation of shock waves."

Dr. Whipple has done much basic work on extremely high-speed ballistics and aerodynamics in connection with meteors and solar system particles in general. He is chairman of the technical panel on rocketry of the International Geophysical Year, a member of the panel on meteorology of the Air Force Scientific Advisory Board, and a member of the Upper Atmosphere Rocket Research Panel, which co-ordinates research by rockets in the United States.

While retaining his professorship in astronomy at Harvard and membership in the Harvard Observatory council, Dr. Whipple will become one of the Solar Associates, a group of scientists responsible for co-ordinating the Harvard research programs with those at the High Altitude Observatory, Boulder, Colo., the Central Radio Propagation Laboratory of the National Bureau of Standards, and the Upper Air Research Observatory of the Air Force.

Some administrative and mechanical work will continue in the laboratories and shops of the Astrophysical Observatory at the Smithsonian Institution in Washington, and the two observing stations in Chile and California will be maintained.

Why Should an Astronomer Study Relativity?

G. C. McVittie, *University of Illinois Observatory*

WHAT PROFIT is there in an astronomer undergoing the mental agony needed to master the intricate and difficult mathematical techniques without which no real understanding of relativity is possible?

The popular answer to the question that I have posed runs somewhat like this: "Einstein proved that Newton was wrong, and therefore, if we do not want to suffer from the illusions that afflicted our predecessors for 200 years or more, we must all become relativists."

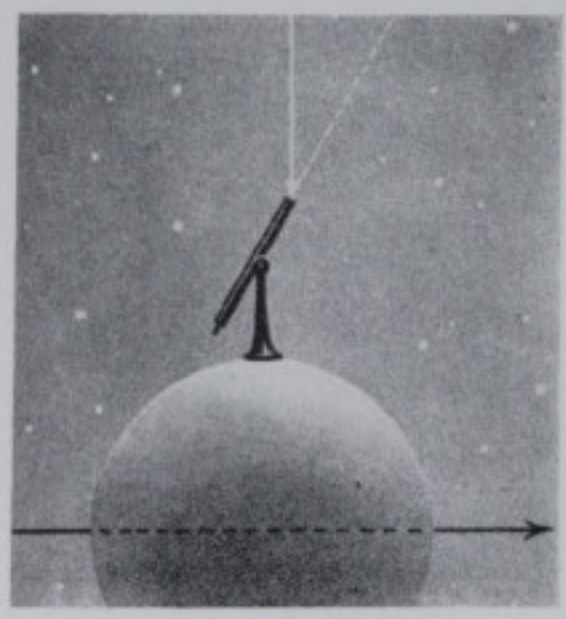
Yet a man who has uttered these words does not hesitate to walk out of the house, drive to an airport, and fly from there to the other end of the country. He performs these actions with little concern, whereas, if he really believes what he has just said, he should make his peace with his Maker, bid a fond farewell to his wife and family, and embark on his journey with no expectation whatever of surviving it. Because every detail of the mechanisms in his car and in the airplane he uses has been calculated in accordance with the theory of Newton and on the firm conviction—rightly held by engineers—that Newton, far from being wrong, is unquestionably right and has been proved to be right to as many decimal places as are needed.

My answer to the question, "Why should an astronomer study relativity?" is quite a different one: By studying relativity we are forced to examine our prejudices about the nature of the physical universe and our preconceptions about such notions as distance, motion, and time, until we realize that these prejudices and preconceptions are not unalterable truths but ideas that we can modify without landing ourselves in contradictions. Once this is grasped, it also dawns upon us that relativity is not, as is often stated, a "revolution in physics." It is instead a method of prizing out of our minds certain fixed ideas with which we have been brought up and that we are usually quite unconscious of holding. It is not physics that is being revolutionized, but the astronomer or physicist, and he rarely takes kindly to the operation.

There is a preliminary question we must ask because both Newton and Einstein are concerned with it. "What is mechanics?" In my view, this discipline seeks to tell us *how* but *not why* bodies move. If we know where a moving object is at the present moment and also what its speed and direction of motion are, can we lay down rules for calculating where it will be and how it will be moving at some later time? These rules, to be useful, should apply to all kinds of motions, to the apple falling in Newton's garden as well as to the moon in the sky, to the motion of an airplane through the air and to the stream of particles ejected by the sun that cause a radio fadeout when they hit the earth.

As to the distinction between the How and Why in the motion of bodies, consider the inverse square law of gravitation. We can say that Newtonian rules of calculation enable us to predict what the planets will do, if we assume that the inverse square law describes a force in Newton's sense of this term. The force is then merely an aid in the process of calculating, and we need not concern ourselves as to whether it exists or not, whether it is real or not. But the moment we say, "The planets move in their orbits *because* the inverse square law of attraction exists and keeps them there," we are encroaching on the realm of the Why.

In doing so, I contend that we are embarking on scientific poetry and overstepping the necessities of our problem, the prediction of planetary motions. Another set of rules, such as those proposed by Einstein in his treatment of gravitational motions, may enable us to perform our calculations just as well and to satisfy the observations just as accurately. What we should have said is that we can describe the present, past, and future motions of the planets by using Newton's rules of calculation, together with his postulated inverse square law of attractive force; but we can also describe them—in some details more accurately, in others perhaps less accurately—by Einstein's rules, together with his postulated curvature of space-time. In either case our system of mechanics enables us to deal with the How of motion, but in neither case have we a clue as to the Why.



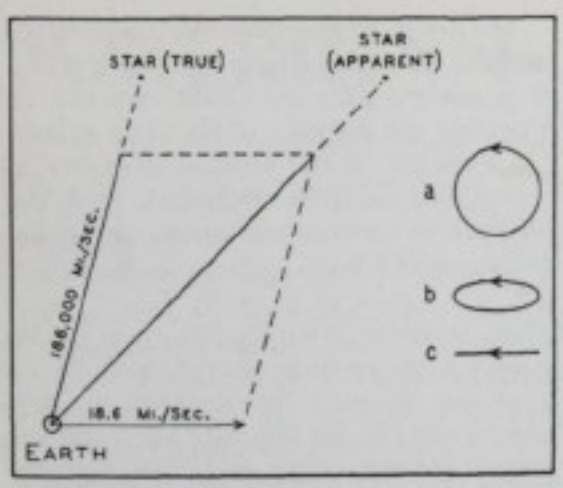
Aberration: The motion of the earth requires that a telescope be pointed ahead of a star's actual direction in space. From "Astronomie," by Rudaux and de Vaucouleurs.

The particular prejudices connected with speed, or velocity, and distance may be examined with a very simple example. When we travel in a car at a steady speed of 50 miles an hour and are overtaken by another car traveling steadily at 60, it is regarded as a self-evident truth that the overtaking car is drawing away from us at 60 − 50 = 10 miles per hour. On the other hand, the relative speed of our own and an approaching car (on the other side of the road, we hope) traveling 60 miles per hour would be 60 + 50 = 110 miles per hour. What, however, do I mean when I say that these are self-evident truths?

By careful examination of the matter, one discovers that consistency is the test of the alleged self-evidence. It has been found that a consistent description of the motions of automobiles can be given if we assume that the relative speed of two cars traveling in the same direction is the difference of their speeds relative to the road; and that if they are approaching one another their relative speed is the sum of their speeds relative to the road. This rule for calculating relative speeds by simply adding or subtracting the speeds of bodies referred to some common standard—in this case, the road—is basic in Newtonian mechanics. But observe, incidentally, that speed is an ambiguous term until we specify the object relative to which it is measured.

It has been found in practice that an immense class of motions of bodies in astronomy, in physics, and in engineering practice, can be consistently described by means of this Newtonian rule for compounding velocities. That it has come to seem like a self-evident truth is simply due to the countless times it has been verified by experiment and observation. But this unfortunately does not guarantee that it will always be true of necessity; we may eventually find types of motion in which application of the Newtonian rule ceases to give a consistent account of the facts.

Light is one entity whose motion, in certain circumstances at least, fails to give consistency when this Newtonian rule is used. As far as laboratory experiments and most astronomical observations are concerned, the speed of light is constant and amounts to some 186,000 miles per second. But certain phenomena in which the speed of light enters are particularly interesting because they illustrate very clearly that the laws of mechanics are



The apparent direction of a star is along the resultant of the velocity of light from the star and the orbital velocity of the earth. A star at the pole of the ecliptic appears to trace a small circle (a) each year; stars in intermediate celestial latitudes trace ellipses (b); and a star on the ecliptic appears to oscillate back and forth (c). The maximum displacement by aberration is 20½ seconds of arc from the star's true direction.

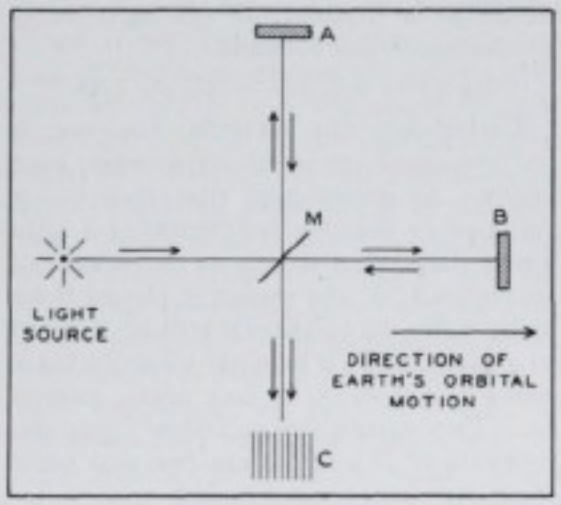
not unalterable truths about nature but merely methods of calculation or ways of interpreting physical data.

For example, there is a well-established astronomical phenomenon called aberration, by which every one of the fixed stars traces out annually on the celestial sphere a small oval-shaped path. This can be interpreted by Newton's rule for compounding velocities as an effect of combining the earth's speed in its orbit (18½ miles a second) with the speed of a light ray coming from a star. As far as this particular application of Newton's theory can be checked observationally, the prediction is in agreement with observation.

But in the latter part of the 19th century, two American scientists, Michelson and Morley, devised an apparatus which provided data of a new kind on the relative motion of light and of the earth. They intended to determine the speed of the earth in its orbit by means of an earth-borne optical experiment. This expectation was based on calculations that made use of Newton's rule for compounding velocities—regarded for two centuries as a self-evident truth. The result of the experiment gave the speed of the earth as zero, within the limits of experimental error, instead of 18½ miles per second. And this was in spite of the fact that Michelson and Morley had shown that their observational technique was delicate enough to detect the earth's motion even if its speed had been very much smaller than 18½ miles per second. Thus, while the phenomenon of aberration is interpretable in terms of Newton's theory, the phenomena observed by Michelson and Morley are not, though at first sight we might expect them to be.

Looking back over seven decades to the stir that the Michelson-Morley experiment made in scientific circles, it is not difficult to recognize its cause. One of the prejudices of the time was that a system of mechanics had to be all-embracing; it was regarded as self-evident that every example of motion had to be consistent with such a system. Today we are sadder, though I doubt if we are wiser men. We are resigned to using three systems of mechanics constructed on logically incompatible bases, Newton's, Einstein's, and the quantum mechanics of the atomic scientists. In a general way, we can associate each system with a different class of phenomena involving motion, and we regard each system as true only within the class to which it refers. All-embracing systems arouse less and less interest, though some of the older scientists, and Einstein in particular, have clung to the hope of producing a unified theory of this kind.

Einstein's interpretation of the Michelson-Morley experiment amounted to the construction of a system of mechanics, different from Newton's, in which the rule of compounding velocities by simple addition or subtraction was replaced by a more complicated one. It could be proved, however, that Einstein's rule reduced to Newton's when the relative speeds were small compared to that of light. In order to achieve this new system, it was necessary to revise certain then-held preconceptions, among others, the idea of distance. Up to Einstein's time it had been supposed that the distance between two objects was an absolute property, that their separation in space was something intrinsic and depended neither on who measured the distance nor on what means were used for the measurement. It is true that different ways of measuring distance had not always given exactly the same result, but it was taken to be self-evident that one of the distances was the "correct" one and that the others were "incorrect."



In the Michelson-Morley experiment, a half-silvered mirror, M, sends part of a beam of light to mirrors A and B, which reflect it back to C, where interference fringes are formed. Classical theory predicts that the fringes should be displaced as the apparatus slowly rotates around M, as a consequence of the difference in travel times of light perpendicular to and parallel to the earth's motion. The special theory of relativity accounts for the lack of fringe displacement as a direct result of the shortening of the apparatus in the direction of its motion—a case of Lorentz-Fitzgerald contraction.

This absolute property attributed to distance was disguised by asserting that the fundamental way of measuring distance was with a rigid measuring rod. But what is a rod of this kind? It is supposed to be a rod the distance between whose ends is absolute, a statement that tells us nothing and is indeed a beautiful example of a circular definition. Furthermore, surveyors use flexible metal tapes that are anything but rigid, and they strive for consistency in their networks of distance measurements. They have laid down rules for the use of their tapes and rules for "corrections" to their readings that will lead to the same distance between Boston and New York whether the original base line from which the triangulation of the United States begins is laid down in Oregon or in Texas.

As we know, one ingredient in the determination of distances within the solar system is the measurement, by surveyors' methods, of the distance between two or more astronomical observatories on Earth. Thus ultimately astronomical distances depend, not on measurements with rigid rods, but on those made with the flexible metal tapes of the surveyor. Once again the test is consistency: Can we describe the dimensions of the sun and planets and their mutual distances, without arriving at a contradiction, by starting from the surveyors' base line measured on earth and working outward? The answer by and large appears to be in the affirmative.

Relativity theory says that we must specify clearly how the distance is to be measured, and by whom. Suppose we agree that it is to be done by observer A using metal tapes. Then observer B, also using tapes of the same kind, but who is in constant relative motion with respect to A, will not assign the same values as A does to the distances between events. The difference depends on the ratio of the square of the relative velocity of A and B to the square of the velocity of light, and is therefore negligibly small for practical purposes on Earth, except when we are discussing the motions of atomic particles, as in cyclotrons or betatrons.

It might be argued that the speeds of planets and stars are also very small compared with that of light, and we can still assume that astronomical distances are absolute. But this would amount to tying down the relativity of the distance between two events solely to the mutual relative speeds of the observers who measure it. We would lose sight of the general principle introduced by relativity theory: The distance between two events is *not* an intrinsic property of the events themselves, quite independent of who measures the distance and by what method. Once a doubt has

been introduced by the demonstration that the relative speed of the observers measuring a distance is an ingredient in its value, we cannot return to the happy belief that all astronomical distances are unique and absolute. If we do, it is by an act of faith.

The speeds of planets and stars are small compared with the speed of light, and this is true throughout the Milky Way galaxy of some two or three billion stars. But are there celestial objects whose motions relative to our galaxy are large fractions of the velocity of light? Up to 30 years ago, the answer would almost certainly have been that there were none. But the 100-inch and 200-inch telescopes of Mount Wilson and Palomar Observatories are providing us with illustrations of high-speed motions of this kind.

A group of spiral galaxies in Grus, all of about photographic magnitude 12. Above are NGC 7599 (left) and 7590. Below them is NGC 7582. North is at the top in this two-hour exposure made with the 60-inch reflector near Bloemfontein, South Africa. Harvard Observatory photograph.

The first step was the realization that our own galaxy is not unique and that there are at least hundreds of millions of other such stellar systems, also called galaxies. The largest were found to be some 100,000 light-years across, while the average distance between neighboring galaxies is of the order of two or three million light-years. When the light reaching us from a distant galaxy is analyzed spectroscopically, there is revealed a red shift of its spectral lines. It was soon established that the fainter a galaxy was, and presumably on the average more remote, the larger was its red shift. E. P. Hubble soon interpreted these observations in terms of essentially Newtonian ideas by saying, first, that the red shift was evidence of a motion of recession; second, that the brightness of a galaxy was an index of its distance; and third, that the relationship between these quantities was: Velocity of recession is proportional to distance.

If the red shift in the spectrum of a galaxy is indeed an indication of relative motion, then these velocities are large fractions of the velocity of light. The greatest published speed is 38,000 miles per second, or about one fifth that of light. Can we, in the light of relativity theory, accept the Newtonian interpretation of the data in terms of a simple proportionality of velocity to distance?

What does an astronomer mean when he says that a galaxy is 8, 25, or 500 million light-years away? How does he connect statements of this kind with the only direct measurement he can make on the more distant objects, the brightness of the galaxy? He observes the apparent magnitude, m, which is a measure of the brightness of the galaxy, and compares this with the absolute magnitude, M, which represents its intrinsic brightness. The latter he arrives at by a variety of indirect means. He then uses m and M to define a distance, D (in light-years), by means of the formula,

$$\log D = 0.2\ (m - M) + 1.51.$$

Underlying this formula, however, is the hypothesis—to which astronomers have become so accustomed that they rarely think of it—that the brightness of a light source falls off inversely as the square of its distance. If the source is placed twice as far away, its brightness will be reduced to a quarter of its original value; if three times as far away, to one ninth, and so on. Two consequences follow from this property of D which were revealed when relativity theory was applied.

The first is that, if a galaxy shows a red shift of amount δ, say, then the formula for D becomes

$$\log D = 0.2\ [m - F(\delta) - M] + 1.51.$$

In other words, D no longer depends on m and M alone but also on F, a certain complicated function of δ. True to his prejudice that D is an absolute distance and that the formula "ought" to be the first and not the second, the astronomer likes to subtract $F(\delta)$ from m and call the result the "corrected" apparent magnitude. Perhaps he would be better advised to call it the "falsified" apparent magnitude!

The second consequence is even more curious. It follows from the theory that D is not the only definition that can be given for the distance of the same galaxy. For example, if the angular diameter of the galaxy could be measured, then the distance so determined would not equal D but would be

$$d = D\ (1 + \delta)^{-2}.$$

Thus, relativity theory shows again in this cosmological problem that distance is not a unique quantity but depends on how you measure it. By means of the apparent magnitude you arrive at D, the so-called luminosity distance; by apparent angular diameter measurement, the distance is d. Neither distance is truer or falser than the other; both are possible definitions of distance and either gives a consistent picture of the data. In practice, the distances of galaxies given in print are always luminosity distances.

Since the distance of a galaxy cannot be uniquely defined, neither can its velocity of recession, for the term velocity is meaningless unless we have stated it as the rate of change with time of some distance. Originally, Hubble tried to short-cut his difficulty by stating that the velocity was simply the red shift multiplied by the speed of light. This is good enough so long as the red shift is small, for the velocity of recession so defined is then indeed the rate of change of luminosity distance. But as soon as we go to larger red shifts and to larger luminosity distances, the relationship breaks down.

In my own view, the interpretation of the data in terms of velocities of recession and distances is unnecessarily complex. If we work in terms of red shifts and apparent magnitudes—the two quantities that are observed—we can construct a theory of the expansion of the universe in agreement with relativity, in which the expansion is not made to depend upon some preselected type of distance. Working on these lines, I have been able to show from the latest available data that the expansion of the universe is, at the present moment, in the process of slowing down. How the brakes are being applied, I cannot tell you; I can only report that this is the result to which the observational data combined with relativity theory lead me.

I have attempted to give some idea of what the impact of relativity on astronomy has been. The data of observation are, as ever, inviolate; it is their interpretation that theory affects. Relativity forces us to examine each step of our interpretative arguments to find out if each apparently self-evident step is really consistent with those that have preceded it. In this way we hope to discover an interpretation which, though it is not true in any eternal sense, is really self-consistent in terms of our present available data.

This article is from a lecture delivered by Dr. McVittie before the Cleveland Astronomical Society, April 1, 1955.—ED.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 92nd meeting of the American Astronomical Society at Princeton, N. J., in April. Complete abstracts will appear in the Astronomical Journal.

Orientation of Galaxies

A marked tendency for the galaxies in a region of the constellation Cetus to have parallel central planes has been found by Dr. S. P. Wyatt, Jr., and F. G. Brown, of the University of Illinois Observatory. While such parallelism had been suggested before, their careful study of 812 galaxies (down to 0.7 minute of arc in diameter) firmly establishes it. They used plates taken with the Curtis Schmidt telescope of the University of Michigan Observatory. So markedly do the longest axes of these galaxies tend to point toward position angle 130° that the probability of this occurring from chance alone is only 1 in 100,000.

These 812 galaxies also show a predominance of edge-on presentation greater than would be expected from chance. This, however, is not necessarily another indication of parallelism; as the authors point out, it may be a selection effect, since edge-on galaxies should have a greater surface brightness and hence be more readily detectable.

This tendency of galaxies to show a parallel arrangement is perhaps of considerable cosmological significance, as it is among the first indications of nonrandom characteristics of galaxies.

Dwarf Cepheids

Several lines of evidence show that RR Lyrae-type (cluster-type) variable stars with periods of less than 1/5 day form a distinct class different from the ordinary RR Lyrae stars of longer period, according to Dr. Harlan J. Smith, of Yale University Observatory.

For two of 11 stars of this kind, trigonometric parallaxes are known; for the others, statistical methods based on proper motions must be used. Their absolute magnitudes appear to range from +4 at periods of 1/20 day to about +1.5 at 1/5 day, making these objects distinctly less luminous than ordinary RR Lyrae variables, whose absolute magnitudes are close to 0.0.

Dr. Smith believes that stars of this new class, which he calls *dwarf Cepheids*, have very small radii. He finds that, with a single dubious exception, none of these stars is known in globular clusters, many of which contain numerous RR Lyrae variables.

Spiral Structure of the Milky Way

In mapping the spiral arms of our galaxy by radio astronomy techniques, the direction and line-of-sight velocities of neutral hydrogen clouds are observed in 21-cm. radiation. The distance of each cloud is inferred from its velocity, with the aid of the theory of galactic rotation.

One puzzle has been that the spiral arms traced in this manner are nearly circular concentric arcs, not converging strongly, as they do in other spiral galaxies that we photograph. Two papers, respectively by Mrs. V. C. Rubin, Georgetown College Observatory, and Dr. F. K. Edmondson, Indiana University, seek to remove this discrepancy by modifying the hitherto simple model of galactic rotation, which postulates circular orbits.

Mrs. Rubin suggests that each hydrogen cloud is moving inward along its spiral arm at 20 kilometers per second, in addition to having the rotational velocity predicted by J. H. Oort. This assumption alters the distances of the clouds, those between galactic longitude 250° and 300° being placed farther from the center, the others closer. The semicircular arm obtained by Oort (*Sky and Telescope*, October, 1954, page 408) is modified so the arm spirals in from a center distance of 11.6 kiloparsecs at longitude 205° to 9.4 kiloparsecs at 345°.

Dr. Edmondson similarly proposes that each cloud is moving, not at right angles to the line joining it with the galactic center, but in a direction four degrees inward. Analyzing the 21-cm. observations on this basis, he obtains the accompanying revised representation of the spiral arms, with strong inward curvature.

The Indiana astronomer pointed out that in the direction from the sun opposite to the center of the galaxy, toward longitude 145° in Auriga, the two ends of the arm seemed heretofore to be at different distances from the center. The diagram showing the angle ϕ equal to 0° indicates this condition, but when his angle of 4° inward is adopted the "kink" is eliminated—the broken ends of the arm point squarely toward one another.

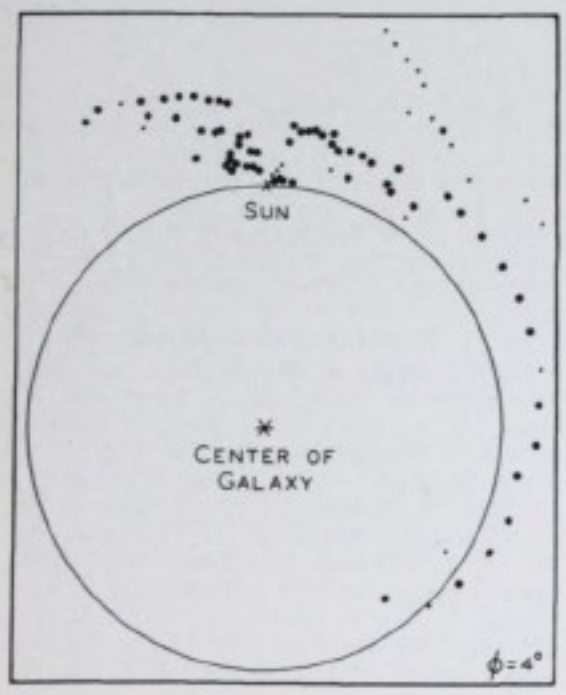
One consequence of both Dr. Edmondson's and Mrs. Rubin's theories would be that the spiral arms of the Milky Way are collapsing inward fairly rapidly.

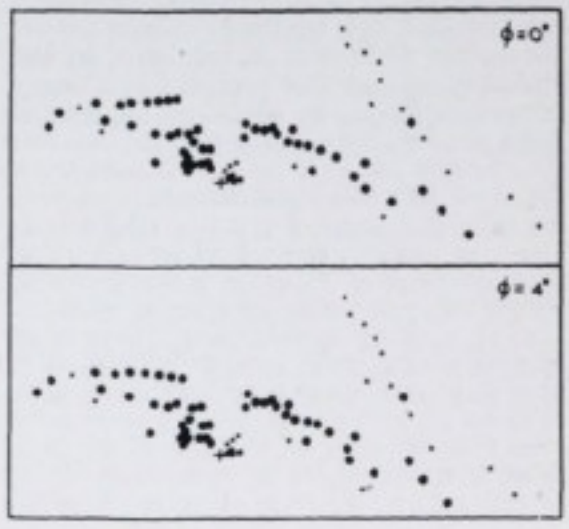
Origin of Solar Flares

The occurrence of solar flares—brief, intensely bright disturbances on the sun that cause radio fadeouts, magnetic storms, and bright auroras on the earth—may be explained by a theory proposed by Drs. W. O. Roberts and D. E. Billings, of the High Altitude Observatory. Earlier hypotheses had ascribed the flares to electrical discharges in the sun's atmosphere.

The Colorado astronomers suggest that an active prominence surging upward above the solar surface could be halted by magnetic fields in the solar atmosphere. As the surge was reflected by the field, there would be an interpenetration of rising and downward reflected material. The kinetic energy of the prominence would suddenly be converted into heat, and an intensely hot spot would then appear on the sun, fading away within minutes or hours.

The total kinetic energy of a surge prominence of fair size (diameter, 30,000 kilometers; height, 70,000 kilometers; mean velocity, 300 kilometers per second) is about 10^{32} ergs, as it passes through the sun's chromosphere. If such a surge is sharply arrested by a magnetic field





Left: This diagram by Dr. Edmondson is based on a motion inward of four degrees. This modifies considerably the map of the spiral arms on page 408 of the October, 1954, issue.

Right: The region near the sun as originally plotted and as modified by Dr. Edmondson. Indiana University diagrams.

Members and guests at the meeting of the American Astronomical Society, Princeton University Observatory, April 3-6, 1955. Photograph by Orren Jack Turner.

The numerical key for this group photograph is simplified to show the last-name initial of each person; to identify a familiar face, it is necessary only to peruse the names with that initial letter in the alphabetical list. The presence or absence of persons known by name can be checked quickly in the alphabetical list.

KEY TO PHOTOGRAPH

1 M, 2 unidentified, 3 S, 4 L, 5 M, 6 R, 7 L, 8 N, 9 M, 10 O, 11 H, 12 B, 13 H, 14 S, 15 M, 16 K, 17 S, 18 K, 19 H, 20 B, 21 W, 22 M, 23 S, 24 K, 25 S, 26 H, 27 R, 28 B, 29 S.

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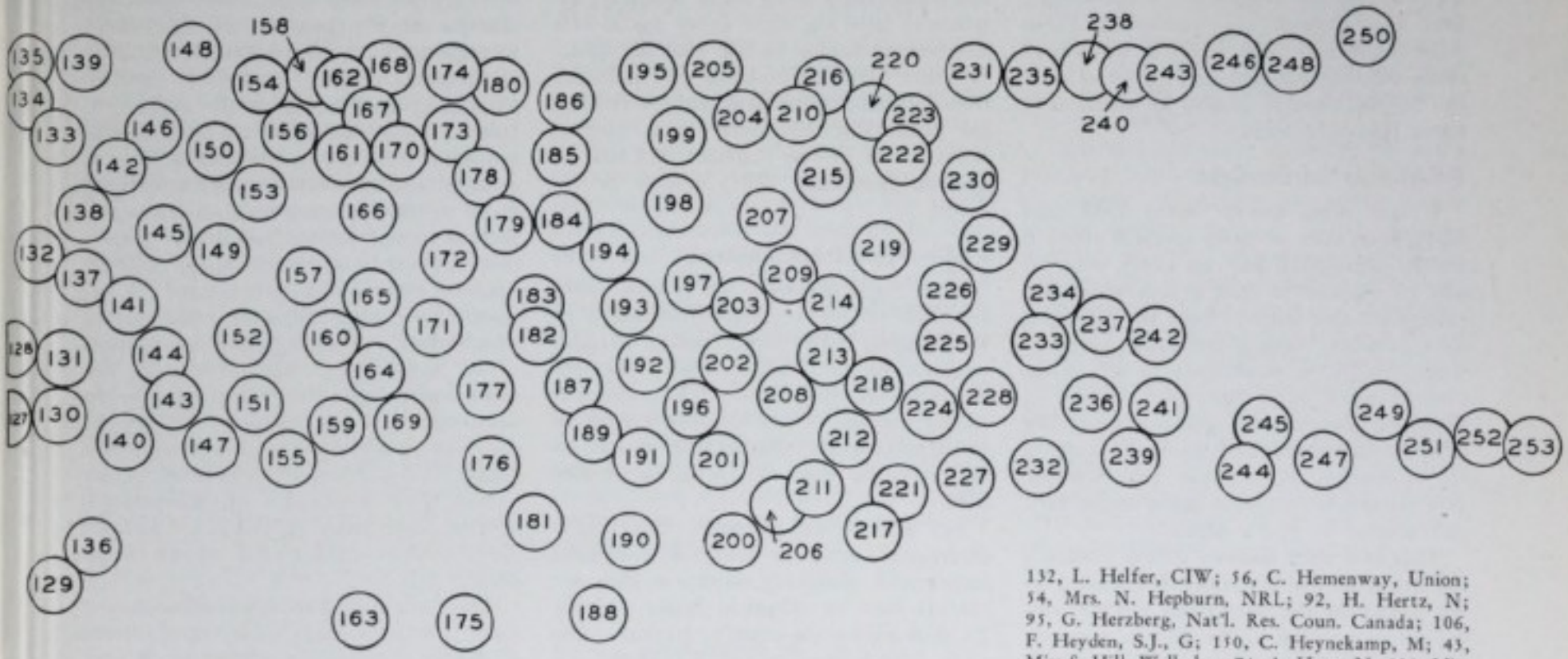

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CIW, Carnegie Institution of Washington; DD, David Dunlap; G, Georgetown; H, Harvard; HA, High Altitude; I, Indiana; Ill, Illinois; LM, Leander McCormick; M, Michigan; McM, McMath-Hulbert; MIT, Massachusetts Institute of Technology; MWP, Mount Wilson-Palomar; N, Naval Observatory; NBS, National Bureau of Standards; NRL, Naval Research Laboratory; OS, Ohio State; Pa, Pennsylvania; Pe, Perkins; Pr, Princeton; RPI, Rensselaer Polytechnic Institute; Sp, Sproul; UA, Upper Air Research Observatory; WS, Warner and Swasey; Y, Yale; Ye, Yerkes.

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of 100 to 500 gauss, and all the energy goes into adiabatic compression, the temperature rise would exceed a million degrees absolute, and the compression factor would be 1,000. Copious ultraviolet radiation, a characteristic of bright flares, would result from such high temperatures and pressure.

In agreement with this proposal are analyses of radio observations by M. Davies, who has suggested independently that the ionized gas producing radio noise associated with flares is simultaneously moving upward and downward at the 3,000-kilometer heights at which most flares probably occur.

Polarization of Starlight

It has been known since 1948 that light from stars of early spectral types is partly plane-polarized, an effect believed due to interstellar dust grains which are elongated and tend to have their longest axes parallel. Such polarization measurements had been made only in the northern sky until Mrs. Elske v. P. Smith, of Harvard Observatory, observed about 200 stars in the southern Milky Way, between the constellations Puppis and Scutum. Her measurements were made at the Boyden station in South Africa.

This new work shows a strong tendency for the planes of polarization (defined by the plane of the maximum electric vector) to be parallel to the galactic equator. The polarization data can be related with the spiral arms of the Milky Way system, as traced by the observations of T. Houck and A. Code, Washburn Observatory, and by Harvard astronomers. In those regions where it appears that we are looking along spiral arms, as in Vela and Carina, the amount of polarization is small, and the directions of the planes of polarization scatter widely. Between Crux and Scorpius, on the other hand, the polarization is far more uniform; apparently here the next inner spiral arm lies perpendicular to the line of sight.

While Mrs. Smith finds that polarization data and spiral structure are related, she points out that local effects, such as polarization by the Coalsack in Crux (at galactic longitude 270°) cannot be ignored.

Radio Noise from Jupiter

Since last summer, at Seneca, Md., scientists of the Carnegie Institution of Washington have been using a radio antenna of the "Mills cross" type for astronomical observations. The antenna system consists of two 2,047-foot rows of 66 dipoles each, intersecting nearly at right angles, and occupying a 96-acre field.

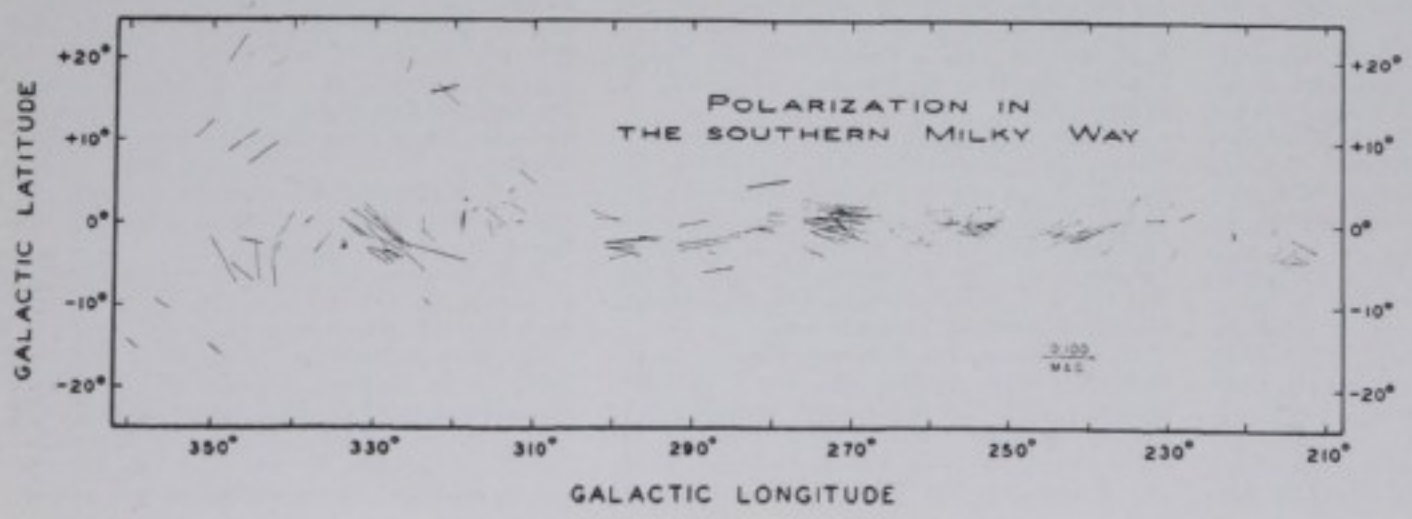
For sky survey purposes, this highly directional array is used as a transit instrument, observing objects as they are carried into its elliptical beam (1.6 by 2.4 degrees) by the earth's rotation. The wave length used was 13.5 meters, corresponding to a frequency of 22 megacycles.

An unexpected finding during a survey at declination +22°, reported by Drs. B. F. Burke and K. L. Franklin, was a very strong source of noise in the direction of Gemini. On nine out of 30 transits in early 1955, very intense, irregular bursts were observed. These occurred only during the six minutes that Jupiter was crossing the beam, and changes in the position of the source corresponded to the normal movement of Jupiter over a period of several months. Uranus, also in the field, was ruled out, for its apparent motion did not agree with that of the source.

Simultaneous bursts have been detected at 10 meters with a simple antenna, but there is some evidence that this phenomenon cannot be observed at 7.8 meters. Further observations are needed to determine the range of wave lengths over which these outbursts occur on Jupiter.

No satisfactory explanation of the radio noise from the largest planet has been advanced. Electrical discharges in the planet's atmosphere, producing radio "static" as terrestrial lightning does, would have to be on an enormously greater scale than on earth to account for the observed intensity of the radio noise.

The Carnegie Institution radio astronomers intend to study Saturn to find out if it also is a radio source.



In this chart, stars for which zero polarization was observed are indicated by small dots. The amount of polarization is proportional to the length of the line for each star. Vela is roughly at 240°, Carina at 255°, Crux at 270°, and Scorpius at 320°. Harvard Observatory diagram.

NEWS NOTES

By Dorrit Hoffleit

IAU CATALOGUE OF DISCRETE RADIO SOURCES

Radio astronomy has progressed to the point where it is desirable to set up a uniform system for cataloguing localized sources. Dr. J. L. Pawsey, president of Commission 40 of the International Astronomical Union, has published in the January *Astrophysical Journal* a catalogue of reliably known discrete sources of cosmic radio noise. The catalogue was compiled early in 1954.

The designation system is to use two numbers for the hours of right ascension, N or S for north or south declination, the tens digit of the declination, and a serial letter, beginning with A for the first known object at a particular position, B for the second, and so forth. Thus, 08S4A designates the Puppis source at $8^h\ 20^m$, $-42°\ 30'$.

For eight objects, accurate positions have been given by a number of observers and their optical identifications have been secured. In some cases, in fact, there is agreement between radio and optical apparent sizes. These objects are optically known as M31 in Andromeda (00N4A); NGC 1275, colliding galaxies in Perseus (03N4A); the Crab nebula, remnant of a supernova in A.D. 1054, in Taurus (05N2A); galactic nebulosity in Puppis (08S4A); M87, a galaxy in Virgo (12N1A); NGC 5128, an abnormal galaxy in Centaurus (13S4A); colliding galaxies in Cygnus (19N4A); and galactic nebulosity in Cassiopeia (23N5A).

The remainder of the catalogue lists 30 objects for which the radio positions are not known so accurately, but for nine of these a reasonable optical identification has been suggested.

EVOLUTIONARY CHANGES IN SINGLE STARS?

Evolutionary changes in brightness or temperature are too gradual to be detected in individual stars, even in the youngest, hottest ones of spectral types *O* and early *B*. Among such stars, however, are the Beta Canis Majoris variables, pulsating stars with periods of about three to six hours. Those with the longer periods are the brighter. Dr. Otto Struve, Leuschner Observatory, suggests that these differing periods may indicate evolutionary trends among these stars.

At the Berkeley meeting of the Astronomical Society of the Pacific in December, he pointed out that the mean density of a *B*-type star would decrease if it evolves with constant mass in such a manner as to describe an evolutionary track away from the main sequence. Furthermore, such a progressive decrease in mean density with age for the star should result in a measurable lengthening of its period.

Of the 10 best-observed Beta Canis Majoris stars, three indeed have changing periods. They are Sigma Scorpii, with a period of 5 hours 55 minutes increasing at the rate of 2.3 seconds a century; HD 199140, 4 hours 49 minutes, 3.0 seconds per century; and Beta Cephei, 4 hours 34 minutes, 1.2 seconds per century. These stars have been under observation for 36, 28, and 50 years, respectively.

At a rate of one second a century, a star like Gamma Pegasi, with a period of 3 hours 36 minutes, would require about one million years to evolve into a star like Beta Canis Majoris, which has a period of six hours. This corresponds well with the accepted age of one to 10 million years for ordinary stars of the same spectral class.

Dr. Struve stated, however, that it may be more probable for the period changes in these stars to be irregular in character. Nevertheless, the possibility that they are evolutionary must not be ignored. He also noted that many years ago A. S. Eddington had considered the changing-period-evolution idea in a problem of Delta Cephei.

ALBERT G. INGALLS RETIRES

An editor's note in the May issue of *Scientific American* announces the retirement of Albert G. Ingalls as editor of the Amateur Scientist department, although he still intends to continue his personal correspondence and discussions among amateur telescope makers. His well-known department was founded in May, 1928, and has appeared under various names, including Telescoptics and The Amateur Astronomer. Its influence was very wide, gaining thousands of recruits to astronomy as a hobby.

"Unk" Ingalls is the editor of the three books in the *Amateur Telescope Making* series. During World War II, he organized amateurs in an extensive program of roof-prism manufacture at a time when roof prisms were in critical supply for military instruments.

IN THE CURRENT JOURNALS

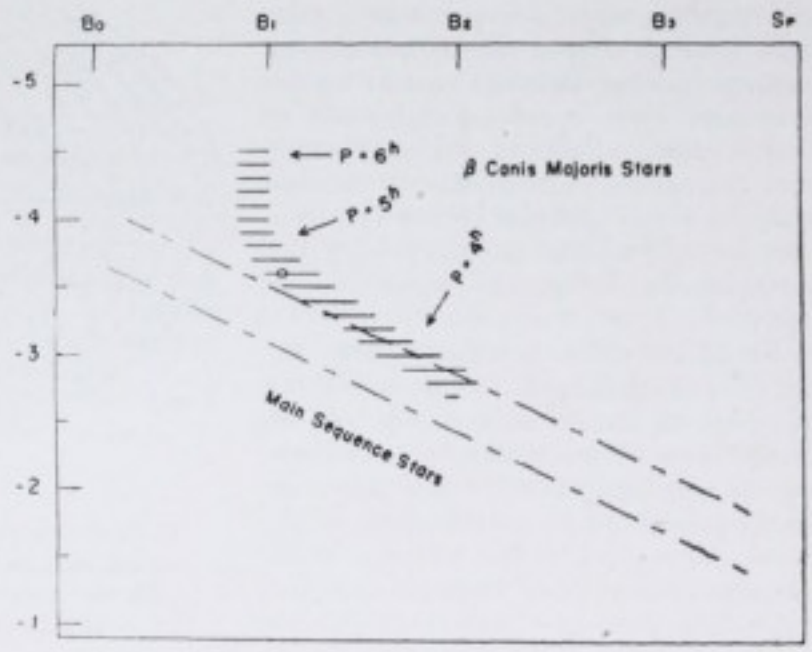
STELLAR POPULATIONS, by R. H. Garstang, *Journal*, British Astronomical Association, February, 1955. "Perhaps the most interesting result of the recent researches on Stellar Populations is the realization that in the Hertzsprung-Russell diagrams, particularly those of Population II, we have been provided with a means of obtaining a much deeper insight into the processes of stellar evolution than has hitherto been attained."

HORIZONS IN ASTRONOMY, by Lyman Spitzer, Jr., *American Scientist*, April, 1955. "There are three areas in which intensive exploration seems likely to yield very fascinating results in the next fifty years. First of all is the structure of the universe. This may be termed the cosmological problem, 'What is the universe like, in its broadest aspects?' . . . The second problem is set by new physical techniques: the problem of radio astronomy. The third topic is more an area than a single specific problem; this is astronomy in outer space, a topic closely related to interplanetary flight."

METEORS AND GEOMAGNETIC ACTIVITY

Recently V. Bumba, of the Czechoslovakian Academy of Sciences, has reported that the earth's magnetic field may undergo temporary changes as a result of meteor showers.

Analyzing the daily geomagnetic index numbers over the period 1890-1937 for the times of activity of seven major meteor streams, Bumba found a slight increase in the geomagnetic numbers shortly after passage of the maximum of a stream. From two to seven days later, the numbers decreased abruptly by six to 27 per cent. Further investigation is needed to confirm these results. Meanwhile, Bumba suggests that the meteors first cause increased ionization in the E layer, and then meteoric dust settles below the ionosphere to shield the earth's surface temporarily from the magnetic effects of ionospheric disturbances.



In this small region of the spectrum-luminosity diagram, the dashes show the region occupied by the pulsating stars of the Beta Canis Majoris type. The data are from a 4½-year program at the Leuschner Observatory by D. McNamara and A. D. Williams. The main sequence is after Morgan and Johnson. Note the relation of period of pulsation and location on the diagram.

The great globular cluster 47 Tucanae, enlarged $2\frac{1}{4}$ times from a 60-minute exposure with Harvard's 60-inch Boyden station reflector. The cluster covers nearly the area of the full moon. Located in the far southern sky, it can be glimpsed from Central America.

Globular Clusters and Their History

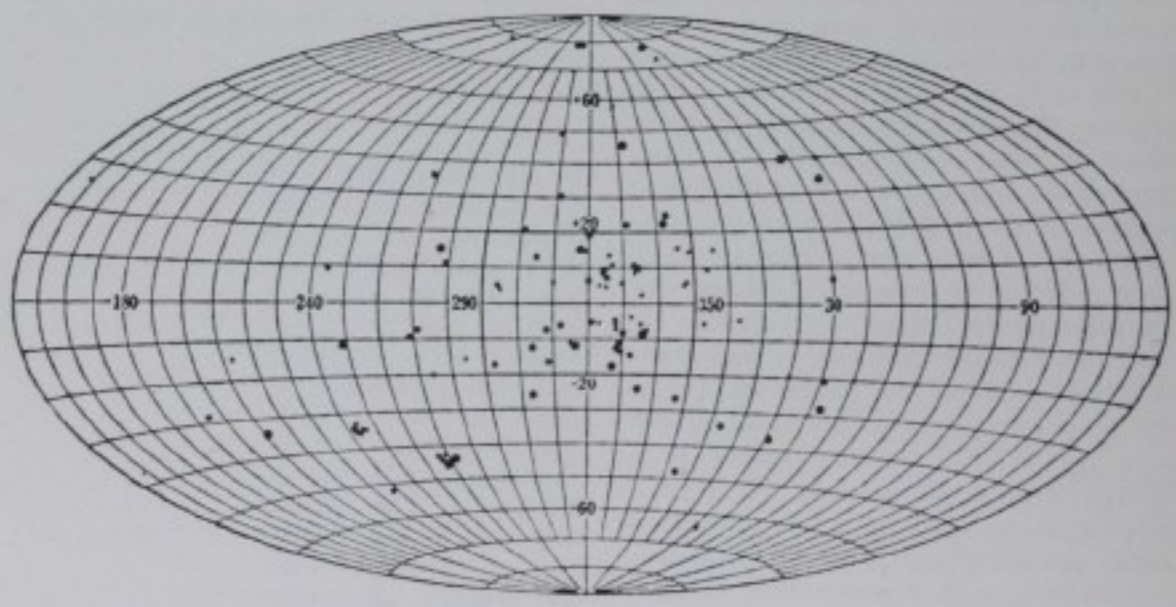
OTTO STRUVE, *Leuschner Observatory, University of California*

THE BRIGHTEST globular star clusters, Omega Centauri (also known as NGC 5139) and 47 Tucanae (NGC 104), are easily visible to the naked eye. Both are located in the southern hemisphere of the sky, and the former was recorded as a star by Ptolemy and as a "lucid spot" by Halley. The brightest globular cluster in the northern sky, Messier 13 or NGC 6205, in the constellation of Hercules, was accidentally discovered by Halley in 1714. It is faintly discernible with the naked eye.

Altogether we now know over a hundred of these objects in our galaxy, and perhaps another hundred remain hidden from our view by obscuring clouds of cosmic dust. Each of these relatively rare formations is exceedingly rich in stars. A single globular cluster may contain several hundred thousand stars, but some appear to be less populous than others.

The distribution of clusters over the sky is illustrated here. There are about as many of them on one side of the central line of the Milky Way as there are on the other side. Few are seen in the galactic plane itself because of the heavy obscuration by dust clouds. Many globular clusters have high galactic latitudes, but their distribution in galactic longitude is far from uniform. There is a heavy concentration in the region of longitude 325°—in the constellation of Sagittarius where the center of our galaxy is located. The half of the sky opposite to that containing the center is nearly devoid of globular clusters.

The globulars are thus connected with the Milky Way, as if they constituted a "skeleton" upon which the galaxy has been built. But this skeleton is not a flattened disk like that containing the spiral arms in which the sun and most of the stars are located. Instead, the globular clusters have a roughly spherical arrangement around the Milky Way. The solar system is to one side of the center defined by the globular clusters—almost 9,000 parsecs or 30,000 light-years away from it.



Each dot represents a globular cluster, plotted on an equal-area chart of the entire sky, in galactic co-ordinates. The horizontal axis is the galactic equator, and the galactic center direction is in the middle, toward which the clusters appear most numerous. From "Star Clusters," by Harlow Shapley.

The distances of the globular clusters are now fairly well known, largely from the work of H. Shapley. Many clusters contain short-period pulsating variables. To illustrate how Shapley utilized them, consider the cluster in Hercules, M13, a 200-inch photograph of which is featured in the center of this issue. The cluster has only a few variables, while others contain hundreds of them. Even so, from four of the variables in M13 Shapley deduced an average apparent magnitude of +15. We know from the cluster-type (RR Lyrae) variables in the sun's neighborhood that their mean absolute magnitude is zero.

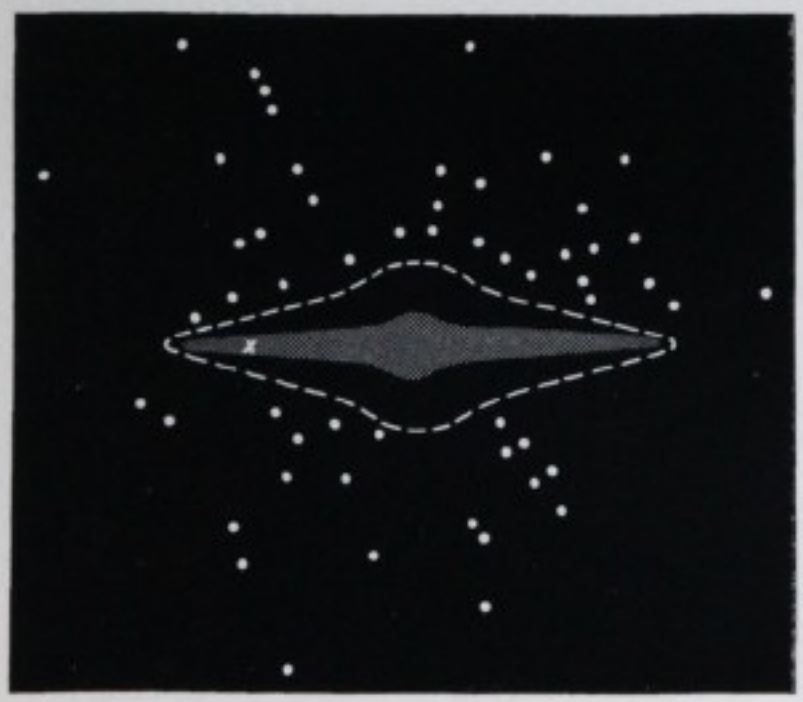
Hence, if M13 were at the standard distance of 10 parsecs (or 32.6 light-years), its variables would have apparent magnitudes of zero—about as bright as Vega! In reality, they appear 15 magnitudes fainter, with an apparent light intensity only one millionth that of Vega. They must be very far indeed. The intensity of light diminishes as the square of the distance. Therefore, the distance of M13 exceeds the standard 10 parsecs by a factor of 1,000, the square root of 1,000,000. Thus, the cluster is about 10,000 parsecs away. A more recent determination by Shapley gives 9,500 parsecs, or some 31,000 light-years, and W. Lohmann makes the distance a little less.

On direct photographs the diameter of M13 is about 18 minutes of arc. At its distance this corresponds to a linear diameter of 50 parsecs, or about 160 light-years. The total number of stars in this cluster is not known. They are too closely crowded in the central regions to be counted. But undoubtedly M13 is a rich cluster, and we may assume that it contains at least 500,000 stars having an average mass equal to that of the sun, 2×10^{33} grams. The *average* density of the cluster is its mass, about 10^{39} grams, divided by its volume, 4×10^{59} cubic centimeters, which gives about 2×10^{-21} gram per cubic centimeter. Other globulars have average densities of the order of 10^{-22}.

Since the stars are heavily concentrated toward the middle of the cluster, the *central* density may easily be 100 times greater. If we could evaporate into gas all the stars of M13 within a sphere of radius 25 parsecs, the resulting nebula would be 10 or 100 times denser than the densest diffuse nebulosity known at the present time in the Milky Way. This must have an important bearing on the problem of the origin of globular clusters and the formation of stars within them.

Omega Centauri, often regarded as the finest globular in the sky, is exceptionally rich in variable stars. This photograph is from a one-hour exposure with the 60-inch reflector of the Harvard southern station.

A remarkable feature of the globular clusters is their almost spherical shape. The photograph of M13 is typical in this respect. At first glance the system looks quite round. But when we view the picture from across the room, we notice that the stars spread farther from the center toward the southeast and northwest than in other directions. I have asked several persons to estimate the orientation of the longest axis of the cluster on the photograph, and most of them agreed, after some vacillation, that it might lie from ESE to WNW. Shapley determined this direction from star counts in different sectors as position angle 125°, counted from north through east—in close agreement with the visual estimates. The apparent oblateness (defined as the difference between the longest and shortest axes, divided by the longest) of this cluster is only 0.05.



Globular clusters, shown by dots, form a spherical halo around the main body of our galaxy (shaded), whose outlying stars are bounded by the broken line. The sun is marked by a cross. After W. S. Krogdahl, "The Astronomical Universe."

Most globular clusters similarly appear slightly elongated. If they are really all oblate spheroids randomly oriented, some of them should have circular outlines. Thus we cannot conclude that any one globular cluster is actually spherical. But since we seldom observe oblateness greater than 0.2, we are quite certain that the polar flattening of these systems is roughly similar to that of Jupiter. But the rotations of the globular clusters must be quite slow, and no rotational motions have been detected either directly or with the spectroscope.

Why, then, are the globular clusters so very nearly spherical? By comparison, the Milky Way, the spiral and elliptical galaxies, and the open star clusters are much more flattened. This question was recently discussed by C. F. von Weizsaecker, of the Max Planck Institute in Goettingen, Germany, in the January, 1955, issue of the *Zeitschrift fuer Astrophysik*. His theory of the evolution of the Milky Way indicates that the globulars have retained their spherical shapes ever since their formation. The von

Weizsaecker theory, similar in some respects to his now well-known eddy theory of the formation of the solar system, may be described as follows:

About six billion (6×10^9) years ago our galaxy was a roughly spherical cloud of turbulent gas with an admixture of dust grains. Encounters of turbulent eddies with one another gradually relieved the turbulence, but any excess of rotation in one direction among the eddies remained as angular momentum within the cloud.

Gravitational effects, according to von Weizsaecker, caused the cloud to break up into smaller cloudlets. Within cloudlets denser than about 10^{-22} gram per cubic centimeter, protostars began to form. From these the oldest stars—of Population II—were formed in this very early stage. Very dense original cloudlets produced the globular clusters, which were sufficiently massive to have strong internal gravity and to retain their identities over very long intervals—hence they are still in existence as clusters today.

Cloudlets of smaller density produced unstable groups of old stars that rapidly dispersed in space, now forming the spherically shaped "halo" of Population II stars including RR Lyrae and W Virginis variable stars, the high-velocity stars, novae, planetary nebulae, some long-period variables, and so on. All of these objects retained, in a general way, the original spherical distribution of the great primordial cloud. Once these Population II stars had been formed, practically none would ever collide with another star, and they continue to travel in orbits around the galactic center—orbits still inclined at all angles to the central plane of the galaxy.

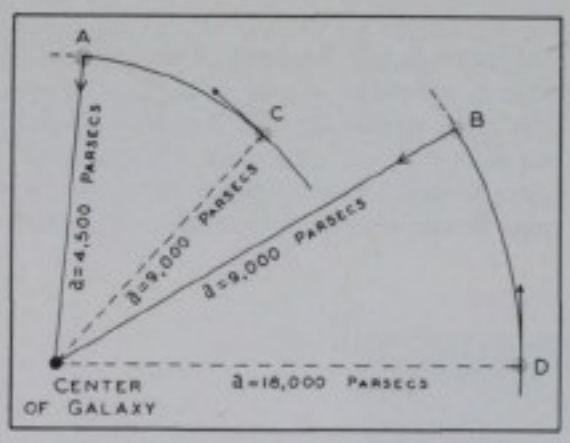
According to von Weizsaecker, however, star formation did not proceed fast enough to exhaust all of the primordial diffuse medium while it remained spherical in shape. The turbulent cloudlets collided frequently, causing them to collapse toward a central plane defined by the accidental tendency of the condensations to rotate more often in one direction than in another. The presence of this residual rotation prevented the cloudlets from falling toward the galactic center. All they could do was form a disk-shaped system of many cloudlets, like the Orion nebula, the dark clouds in Taurus and in Ophiuchus, and so forth. Thus, about five billion years ago the Milky Way appeared as a disk of gas and dust, with spiral arms in the plane of the disk, and with a halo of old stars and globular clusters all around it.

Star formation continued during this second stage of evolution, and as a result we now observe in the galactic plane many stars of considerable age. The sun is one of them, and we shall not be far wrong if we attribute to it an age of five billion years. The cloudlets of the disk continued to collide with each other, as they revolved around the galactic center with periods ranging between about 100 million and 300 million years. (In his earlier work von Weizsaecker had shown how friction in this galactic medium had tended to collect the innermost cloudlets into a relatively dense galactic nucleus, while the peripheral cloudlets tended to move outward in the plane, perhaps producing the spiral arms.)

Meanwhile, stars kept on forming within the central nucleus and also within the spiral arms. At present, the diffuse matter of the nucleus is mostly exhausted. The remaining cool hydrogen gas discovered in the nucleus by radio astronomers is relatively thin and can contribute little to the formation of new stars. But in the arms great clouds of gas and dust are even now condensing into stars—those we call Population I. Some of them are probably less than one million years old!

If this picture is correct for the whole primordial cloud, it must also hold individually for cloudlets, such as those that produced the globular clusters about 5½ billion years ago. Yet, the individual clusters do not have pronounced central planes or appreciable amounts of obscuring dust or gas. Have the globular clusters lost their disks after their formation, or were they somehow prevented from forming such disks? Von Weizsaecker favors the second alternative.

At this point we must consider the kinds of orbits globular clusters might pursue around the mass concentration at the center of the galaxy. Because of this concentration, we can draw a rough analogy with orbits in the solar system, in which all objects obey Kepler's laws. The planets have nearly circular orbits, but the paths of some long-period comets are very elongated, with the sun near one end. The motion of a comet in such a highly eccentric orbit is extremely rapid at perihelion, but when farthest from the sun the same comet will move very slowly, before once again falling in toward perihelion. Are the orbits of globular clusters predominantly circular, or are they so highly elliptical as to be practically radial with respect to the galactic center?



These schematic globular cluster orbits illustrate the extreme cases studied by S. von Hoerner. Cluster A, 9,000 parsecs from the center, is near the apogalacticon of a radial orbit of eccentricity practically one; the cluster is now virtually stationary with respect to the galactic center, yet will move with high speed when near the center. The semimajor axis of this radial orbit, a = 4,500 parsecs, is half the distance from the center. Cluster B is similar to A, but its distance is 18,000 parsecs. Clusters C and D have circular orbits, with motions of 260 and 190 kilometers per second, respectively. Their semimajor axes are equal to their distances from the center.

The distances of the clusters from the sun are well determined; the most recent discussion is Lohmann's in 1952. Since we also know at each cluster the angle (θ) between the sun and the galactic center, whose distance from us is 9,000 parsecs, we can compute the distances of all clusters from the galactic center. The most distant ones are about 50,000 parsecs from the center, which value would then be the radius for a circular orbit of such a cluster. If the cluster has an almost rectilinear, radial orbit, like those of some comets in the solar system, its semimajor axis would be about 25,000 parsecs.

Kepler's third law states that the squares of the periods are proportional to the cubes of the semimajor axes. For the sun's orbit around the galactic center, the period is 200 million years and the semimajor axis 9,000 parsecs. For a distant globular cluster the latter quantity is between 50,000 and 25,000 parsecs, corresponding to periods of 2½ and 0.9 billion years, respectively. Thus, even the most remote globulars have galactic periods which are well under the 5½ billion years since the clusters were formed. Less remote clusters have shorter periods; for example, M13 in Hercules has a period of 200 million years if the orbit is circular, or as little as 70 million if it is radial.

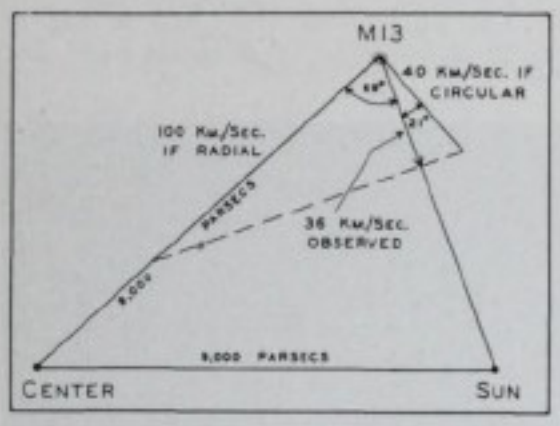
This means that every globular cluster has made repeated circuits of its orbit since its formation. If during such a cycle it passed through the dense central plane of our galaxy, then the diffuse matter remaining within the cluster would have collided with the nebulosities of our galactic disk and would have been swept out of the cluster. But the cluster stars would pass through the galactic disk almost unaffected. They would have had practically no chance to collide with the stars of Population I, and they would not be greatly affected by the resisting action of the nebulosities. The cluster would proceed on its way with its original spherical arrangement of stars but robbed of its diffuse medium. Most clusters would experience this effect quite early in their lives and would be unable to evolve a disk-shaped system of nebulosity and young stars, as did the Milky Way as a whole.

The fundamental idea used by von Weizsaecker in the foregoing paragraph is, as he remarks, borrowed from W. Baade and L. Spitzer, Jr., who in 1951 jointly

pointed out similar consequences of a collision between galaxies.

If the globular cluster orbits are predominantly circular, the more distant clusters would never encounter dense central regions of the Milky Way. The hypothesis of von Weizsaecker will work only if the orbits are so strongly elongated that the clusters penetrate the hub of the galaxy. This aspect of the problem has been discussed by S. von Hoerner, also of the Max Planck Institute.

Consider again M13, which von Hoerner places at 9,000 parsecs from the galactic center, the same as our distance from that center. The radial velocity (line-of-sight motion) of M13 has been measured by N. U. Mayall at Lick Observatory, who found it approaching us at 228 kilometers per second. Most of this relative motion is due to the sun traveling in its own circular galactic orbit at a speed of 260 kilometers per second toward Cygnus, of which 173 kilometers per second is in the direction of M13. The sun's additional small motion with respect to the neighboring stars is 20 kilometers per second toward Hercules, 19 of which is in the direction of M13. The remaining motion of 36 kilometers per second toward us is the component, in our line of sight, of the cluster's orbital velocity.



At the globular cluster M13 the angle θ is 69°. We observe the cluster's speed of approach as 36 kilometers per second (after allowing for the sun's motion). This is only the projection on the line of sight of the true velocity of the cluster in its orbit around the galaxy. If the orbit is circular, the cluster's speed is 40 kilometers per second. For the other extreme possibility, that of an orbit so elongated as to be practically a radial line, the orbital speed would be 100 kilometers per second. It is this latter case of radial orbits that von Hoerner finds to be characteristic of globular clusters.

But from this alone we cannot tell the real space motion of M13. If the cluster has a wholly radial motion toward the galactic center, it is moving nearly 100 kilometers per second; if its motion is in a circular orbit, it would be revolving in a retrograde direction at 40 kilometers per second. Without additional information, however, we cannot choose between these two assumptions.

How far from the center can M13 get, if it has a radial orbit? At our distance from the center, the sun's velocity of 260 kilometers per second would correspond to a maximum galactic distance (at apogalacticon) of 18,000 parsecs for a radial orbit; the 100 kilometers per second of M13 corresponds to only 10,000 parsecs. The motion of M13 is now toward the center. After some 50 million years it will have passed to the center and back again, reaching its present location with the same velocity of 100 kilometers per second, this time directed away from the center. It will move out only another 1,000 parsecs before turning in again. At present, then, it is 9/10 of its greatest distance from the center.

Although we have used M13 as an example, actually in any single case the radial velocity is not sufficiently well known to place much reliance on the resulting components. But the entire material on the motions of the clusters obtained by Mayall is certainly significant, and von Hoerner has used a clever statistical procedure first developed by F. K. Edmondson in 1937 to determine whether globular cluster motions are predominantly radial or circular.

In the diagrams below, one shows the case for circular orbits, where clusters making small angles with the galactic center in the sky (θ near 0°) would have small line-of-sight motions as seen from the earth. But were their orbits of the radial type, these same clusters would show large line-of-sight motions. Similarly, all those clusters for which θ is near 90° would show large motions if their orbits were circular and small motions if their orbits were straight lines directed to the nucleus of the galaxy.

Von Hoerner has computed for all the 50 Mayall cluster velocities the component in the line of sight remaining after allowing for the two motions of the sun. For 46 objects, those with θ between 0° and 45° have average line-of-sight motions of 106 kilometers per second, those between 45° and 90° only 74 kilometers per second. We conclude that the hypothesis of rectilinear motions is strongly favored.

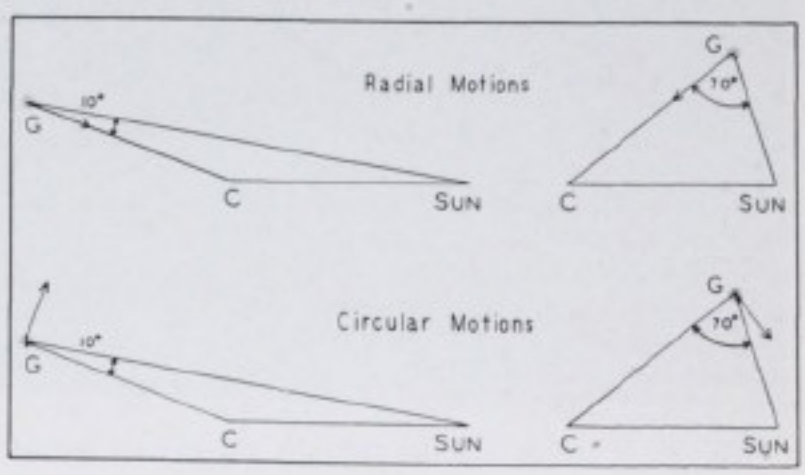
Almost one half of the clusters are moving too fast for circular orbits at their respective distances from the nucleus, von Hoerner points out. For example, NGC 2298, for which θ is 18°, is moving toward us at 187 kilometers per second. If this is the line-of-sight component of a circular orbit, the real orbital velocity would be 600 kilometers per second. But NGC 2298 is 26,500 parsecs from the galactic center. At this great distance, the circular orbital velocity is only 150 kilometers per second; hence, the cluster cannot be following such a path.

On the other hand, if its velocity of 187 kilometers per second is in a radial orbit, the cluster is at present only 0.15 of its apogalactic distance from the center, which is an entirely possible result.

Still another criterion points toward radial orbits. Kepler's second law predicts that the clusters will spend most of their lives near apogalacticon if their orbits are of the radial type. Hence, the distribution of the ratios of present distance from the center to apogalacticon distance should show very few small values and increasingly many large values. The result is just as expected, the mean value of this ratio being close to 0.9, and there are only three clusters for which it is less than 0.5.

Von Hoerner concludes that nearly all clusters with present distances greater than 14,000 parsecs have almost rectilinear orbits, and that only about 30 per cent of the nearer clusters can have circular orbits. This conclusion adds to the interest of von Weizsaecker's hypothesis.

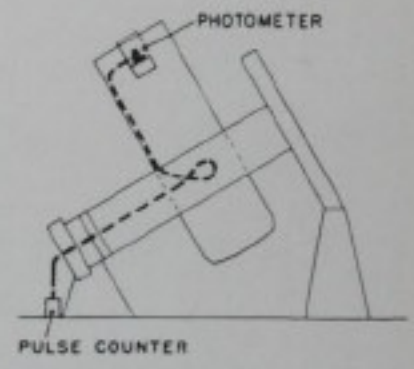
A by-product of this work is the conclusion that the original cloudlets out of which the globular clusters were formed must have been much more dense than the nearby nebulosities of the Milky Way are today. We have already seen that the present population of stars in a typical cluster requires an initial density of the order of 10^{-22} gram per cubic centimeter. If, in the process of passing through the disk of the Milky Way, such a cluster lost a good fraction of its original mass, it must have been even more dense to begin with. It is probable that 5½ billion years ago the spherical galaxy contained some very dense cloudlets of a kind the Milky Way does not now possess.



For a globular cluster, G, located in various directions from the sun and the galactic center, C, the relation of its orbital and apparent motions is shown. The value of the angle θ is given in each case.

COUNTING PHOTONS — One by One

WILLIAM A. BAUM, *Mount Wilson and Palomar Observatories*



PART II

IN photoelectric photometry of the faintest stars, the expected advantage of charge integration methods, which we discussed last month, has been thoroughly confirmed by the performance of the photon counter now in use on the 200-inch telescope. The photometer unit that attaches at the prime focus is shown in Fig. 6, and Fig. 7 is a schematic diagram of the complete photometer.

Units above the dashed line in Fig. 7 are located in the prime-focus cage with the observer (see page 264, May issue). Units below the dashed line are located in a small enclosed room beneath the telescope, where a lamp can be used by the night assistant. His job includes setting the telescope, keeping track of the data, and entertaining the observer.

The instrument presently includes one photon-counting channel and one d.c. channel. The latter is at the right-hand edge of the diagram and has three functions: It serves as a standby in case the counter fails; it is needed for stars brighter than 14th magnitude (which exceed the speed limit of the counter), and it can be used for scanning extended objects.

The photometer unit, seen in Fig. 6, is 22 inches wide by 18 inches high, and

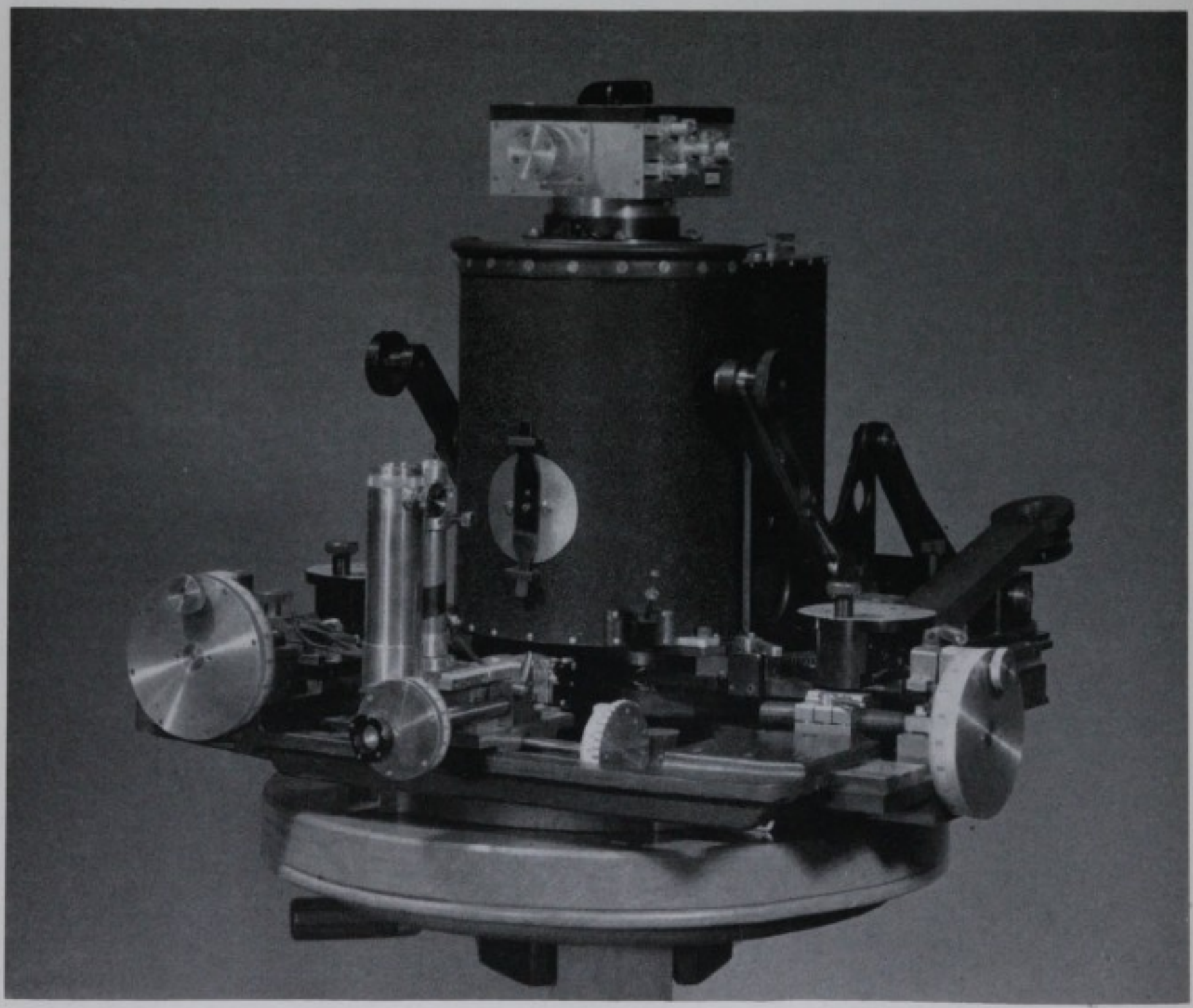


Fig. 6. This unit of the 200-inch photometer is mounted onto the prime-focus pedestal, light entering it from below.

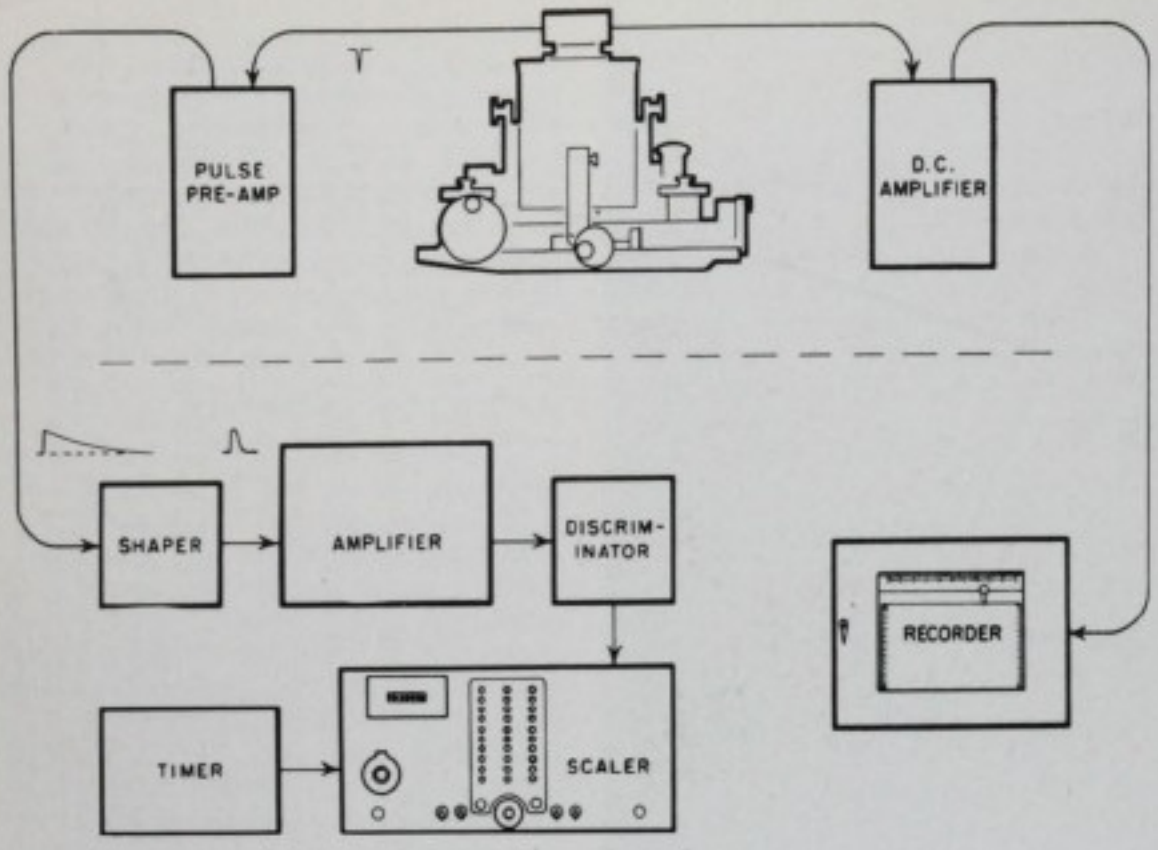


Fig. 7. The arrangement of the parts of the 200-inch photometer.

weighs about 90 pounds. It includes the photomultiplier tube, refrigeration chamber, color filters, focal-plane diaphragms, guiding eyepiece, and offset mechanism. Two large calibrated screws, seen here at the extreme left and right, provide precise *x* and *y* offset motions for setting on faint objects, as described last month. Motors can be attached to these screws for scanning extended objects. The guiding eyepiece, vertical in the left foreground, is also equipped with calibrated *x* and *y* motions.

At the center of the picture is the photometer head which contains the photomultiplier, as shown in Fig. 8. Inside the mounting below it are two large disks, one carrying 10 focal-plane diaphragms, and the other accommodating 10 2-by-2-inch color filters. The focal-plane diaphragms now in use have diameters ranging from 0.25 millimeter (0.01 inch) to 10 millimeters.

When you want to view a star field in preparation for some measurements, you simply swing the photometer head back out of the way on parallel pivots so an eyepiece can be brought into place. Since the unvignetted field through the filters is about 1.5 inches, the same mounting can also be used for experiments with image-receiving devices.

As Fig. 8 indicates, the photometer head contains an Emitron 6685 end-on photomultiplier, which actually has 14 dynode stages. Just ahead of the photocathode is a Fabry lens whose function is to focus the exit pupil of the telescope onto the photocathode. This makes the photometer immune to variations in the distribution of light across the focal-plane diaphragm such as are encountered in poor seeing or in a photometric comparison of galaxies with stars.

Surrounding the multiplier tube is a four-liter dry-ice chamber sufficiently well insulated to maintain continuous refrigeration with daily fillings of crushed dry ice. It happens, however, that the present Emitron multiplier is of such high quality that refrigeration is unnecessary, even for 23rd-magnitude observations. The dark count at dome temperatures is always small compared with the sky background count. It ranges from one to 10 counts per second between winter and summer.

The signal from the photomultiplier goes first to a pre-amplifier located in the prime-focus cage and thence by coaxial cable to the cabinet shown in Fig. 9. This cabinet, which contains the rest of the photon-counting system, is located in the room near the coude focus. Here the night assistant controls the counting intervals and records the data according to instructions received from the observer over an intercom system. In this cabinet certain commercial units have been adapted with modifications, but the more critical components were designed and fabricated at the observatory.

Now, referring again to Fig. 7, let us follow pulses through the system and see what happens to them. When light falls upon the cathode of the photomultiplier tube, about one out of every 20 photons ejects an electron. Each electron leaving the cathode strikes the first dynode where it ejects several secondary electrons. These are accelerated to the second dynode where they eject more secondary electrons, which in turn are accelerated to the third dynode, and so on. After secondary multiplication has taken place at 14 dynodes in succession, the original photoelectron has been snowballed into a pulse of a million electrons, on the average. This charge is collected by the anode and dumped onto a condenser of $10\mu\mu f$ at the input of the pre-amp, from which it leaks off through a resistance of one megohm. The resulting pulse seen at the input grid of the pre-amp has a steep rise of 10^{-8} second and a decay constant of 10 microseconds.

The pre-amplifier is a simple two-tube feed-back circuit having a voltage gain of 0.5 and an output impedance of 90

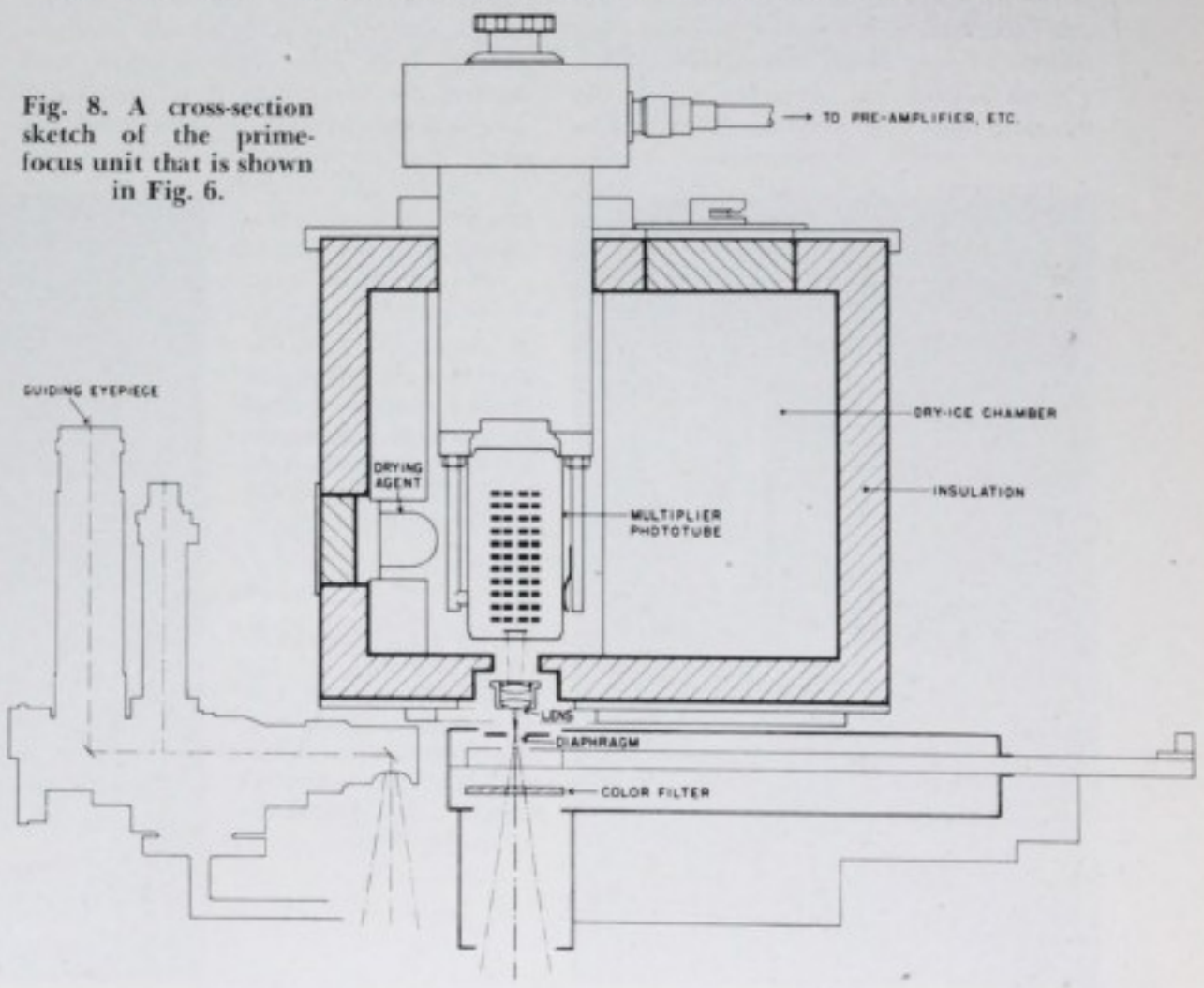


Fig. 8. A cross-section sketch of the prime-focus unit that is shown in Fig. 6.

ohms to match the RG-62U coaxial cable 150 feet long which it feeds. The shape of the pulse coming out of the pre-amp is the same as that already described, except that its sign is positive and the average pulse is now 10 millivolts high.

At the other end of the cable, the shaper into which this pulse goes is essentially a one-microsecond delay line. The reflected pulse cancels the tail of the incoming pulse, changing the latter from the shape shown in Fig. 7 above and left of the box marked "shaper" to the form shown between the shaper and amplifier boxes.

The pulse amplifier has two three-tube feed-back loops providing an over-all gain of 2,000. It builds the average pulse up to a height of about 20 volts with very little change in shape. At half-height, the pulse is one microsecond long.

The discriminator is a Schmidt-type trigger circuit, whose function is to reject all pulses smaller than a prescribed height and to pass on the rest as square pulses all of the same size. The foregoing paragraphs pertain only to an "average" pulse, whereas the pulses from the multiplier actually range very considerably in size. Two distinct phenomena enter into the production of pulses. One is the ejection of electrons by photons incident upon the cathode. The other is the thermal evaporation (called dark emission) of electrons from both the cathode and the dynodes. Most of the thermoelectrons originate from the dynodes, because the dynode areas are large in comparison with the cathode area (0.8 square centimeter). As a result, most of the "dark" pulses pass through fewer stages of multiplication than cathode pulses do. This means that there are zillions of very small dark-current pulses ("grass") from the dynodes which the discriminator can exclude while transmitting the majority of the cathode pulses. In practice, this is done by setting the level of the discriminator at about half the average height of cathode pulses.

The scaling circuits are standard commercial units that count to 10 each and can distinguish between pulses 1/200,000 second apart. Digits, tens, and hundreds are registered in columns of neon lights, seen in the middle of the center panel of Fig. 9, while thousands and above are registered on the mechanical counter to their left. Since this mechanical counter cannot operate at more than six steps per second, the input speed is limited to 6,000 counts per second, which corresponds to about 14th magnitude, as mentioned earlier. At that brightness level, the statistical correction due to the limited resolving time for pulse pairs reaches three per cent. Also at that level, the mechanical "thousands" counter sounds like a riveting hammer.

This is the operating procedure: After the observer in the prime-focus cage has centered a faint star in the diaphragm by the means already described, the night assistant starts the timer, and the scaler automatically starts registering. At the end of 100 seconds, the timer automatically stops itself and simultaneously terminates the count. While the observer shifts the diaphragm to a vacant sky patch, the assistant records the count and resets the scaler. A sky count of 100 seconds duration is then taken in exactly the same manner. Alternate counts of 100 seconds each on sky and star-plus-sky are continued in this way until the total accumulated time on each reaches t prescribed by the formula given on page 267 last month. As already mentioned, the purpose of breaking up the total exposures into 100-second intervals and shifting the diaphragm is to cancel any slow change in the brightness of the night-sky background. With certain complications, this could also be done by arranging two complete channels to count simultaneously through two diaphragms.

M 31, STAR 21, 0.4 MM DIAPHRAGM. P_e = 21.9 ± 0.2, C = +1.3

BLUE				YELLOW			
Star + Sky (n + N)	Sky (N)	Star (n_1)	Star (n_2)	Star + Sky (n + N)	Sky (N)	Star (n_1)	Star (n_2)
	4760	−114			6154	+113	
4646				6567			
	4607	+112	+ 39		6170	+271	+ 97
4719				6441			
	4609	+190	+110		6295	+178	+146
4799				6473			
	4675	+ 12	+124		6299	+ 58	+174
4687				6349			
	4743	− 45	− 56		6180	+ 30	+169
4698				6210			
	4717	+120	− 19		6290	+ 57	− 30
4837				6287			
	4582	+151	+255		6373	+262	+ 14
4733				6535			
	4625	+221	+108		6439	+ 18	+ 96
4846				6457			
	4752	+ 34	+ 94		6410	+293	+ 47
4786				6803			
	4759	+ 46	+ 27		6731	− 31	+ 72
4805				6700			
	4754	+ 77	+ 51		6476	+272	+224
4831				6748			
	4725	+ 69	+106		6620	+114	+128
4794				6754			
	4621	+134	+163		6612	+191	+122
4765				6803			
	4712	+ 64	+ 53		6882	−120	− 79
4776				6762			
	4681	−101	+ 95		6784	+157	− 22
4580				6941			
	4635		− 55		6565		+376
Mean n =			+69	Mean n =			+117
p.e. from scatter =			±16	p.e. from scatter =			±22
$0.675\left(\frac{2N+n}{t}\right)^{1/2}$ =			±17	$0.675\left(\frac{2N+n}{t}\right)^{1/2}$ =			±20

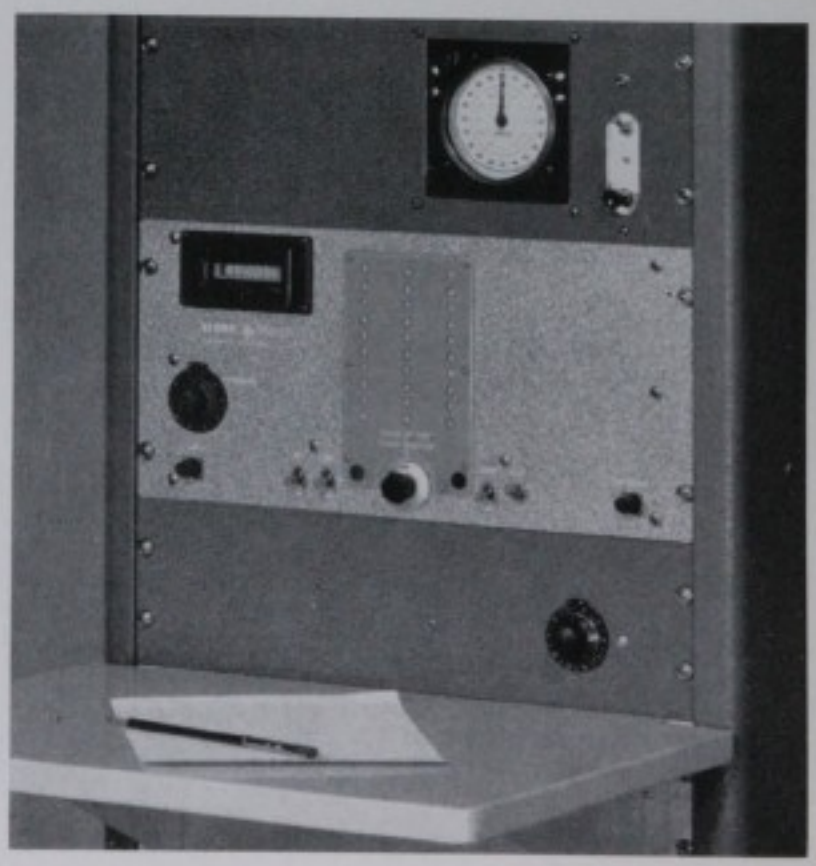
Fig. 10. A sample set of photon counts on a 24th-magnitude star.

The faintest object thus far measured by photon counting—or, for that matter, by any method at all—is a red giant star in the halo of the Andromeda galaxy. It was found to have a blue magnitude of 23.9 and a yellow (photovisual) magnitude of 22.6. Accordingly, its color index is +1.3 and its absolute magnitude is about −0.3 photographic.

The actual photon counts on this star are given in the table reproduced as Fig. 10. The first column under each color

Fig. 9. Left: The part of the apparatus located in a room below the telescope includes most of the electronics of the photon-counting system.

Right: An enlargement of a portion of the panel shows the 100-second timer at the top, the bank of neon lights, and the mechanical counter for thousands and above.



lists the counts registered in 100-second intervals with the star centered in the diaphragm. The second column under each color is for sky counts in 100-second intervals alternated with those in the first column. Subtraction of individual counts in the second column from adjacent counts in the first column may be done in two ways, as this example from the blue figures shows:

$$n_1 = 4719 - 4607 = +112$$
$$n_2 = 4646 - 4607 = +39.$$

To list both n_1 and n_2 is, of course, partly redundant, but they serve to illustrate how the individual differences, which represent the pulses for the star alone, scatter widely. The subtraction process corrects for drift in the instrument and changes in the sky background.

In the blue, the mean contribution of the star was 69 counts per 100 seconds. The probable error of this mean computed in a conventional way from the scatter of the data is ±16, while the probable error theoretically to be expected from pure statistics is ±17. Similarly in the yellow, the observed scatter yields a probable error in good agreement with theoretical expectation. This agreement means that the performance of the photometer approached that of an *ideal* instrument operating at the same quantum efficiency; that is to say, every last drop of information is being squeezed out of the photocathode. It also means that the formula for t can be taken at face value.

On a fully exposed photograph in the yellow, the 22.6-magnitude image of the red giant star of Fig. 10 can be discerned just well enough to determine its position. However, on a fully exposed photograph in the blue no image can be detected. In other words, 23.9 magnitude is beyond the limit of the photographic plate but still within reach of the photon counter. In principle, it should be possible with the counter to obtain rough measures as faint as 25th magnitude within a reasonable number of observing hours, if the locations of such objects were known. Unfortunately, one must still depend upon photographs to tell where objects are located.

There is one qualification that must be attached to these considerations. The photoelectric measurement of a star that lies near (or perhaps even beyond) the photographic threshold is very much at the mercy of still fainter stars, which presumably populate the background and which are likely to be included unwittingly in the focal-plane diaphragm. The selection of a supposedly vacant sky patch is literally a shot in the dark. On the basis of other astronomical information, the odds of encountering background troubles in a particular field can usually be estimated, but the risk cannot be eliminated.

The superiority of photoelectric detection would be even more evident if practical limitations didn't force one to use a diaphragm considerably larger than the seeing disk within which most of a star image is concentrated. In effect, this means that a picture-receiving system employing a photoelectric cathode should have a large potential advantage over a photographic emulsion if a completely successful system could be designed. In a sense, this potential advantage has been obvious for a long time, from a simple comparison of photographic and photoelectric quantum efficiencies, but the state of the art of photoelectric image systems has only recently justified realistic hopes. The problem is now receiving attention, and some practical developments were described by Otto Struve in his article in the April issue.

The cosmological problem outlined at the beginning of this article last month provided the main impetus for designing and building the Palomar counter. The effort has really paid off, and the preliminary results are exciting. It is already clear from measures on galaxies, in clusters with known red shifts, that distances of galaxies judged from their apparent sizes (determined photometrically) are not in agreement with distances judged conventionally from apparent luminosities. This disagreement implies that we are encountering evolutionary changes or intergalactic obscuration or a combination of these, and indicates that previous distances based on apparent photographic luminosities are of doubtful meaning.

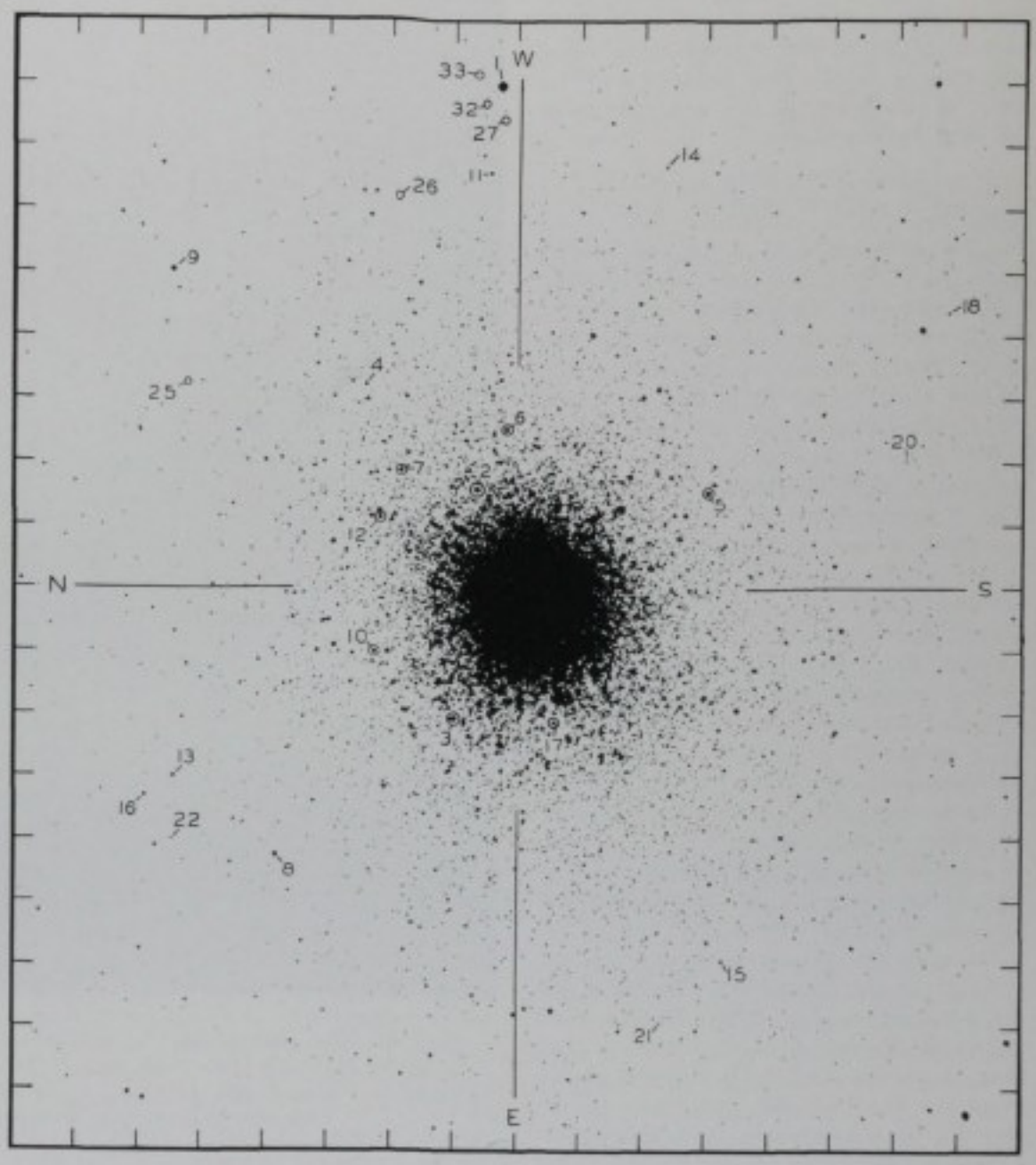
Fig. 11. The great cluster of galaxies in Corona Borealis, from a negative made with the 200-inch Hale reflector. In an area of the sky equal to that of the moon, there are about 400 galaxies, most of them ellipticals, according to Hubble. Mount Wilson and Palomar Observatories photograph.

The Corona Borealis cluster of galaxies shown in Fig. 11 is one of six large clusters selected for detailed study in a first attempt to explore the problem. This cluster's red shift is 22,000 kilometers per second, but its true distance is not yet known. Photographic estimates placed it at about 40 million parsecs. Since the photoelectric observations involve the photometric sizes of individual galaxies, excellent seeing and a precise technique of measurement are required, especially for the members of the more distant clusters. It may be quite a while before definitive results can be accumulated.

Galaxies in the local group and in other nearby groups comprise the sample upon which a cosmic yardstick must be

based. The extensive photometry of distance indicators, such as Cepheids and novae, belonging to these nearby systems can be handled fairly well by photographic methods if the data are properly calibrated on a correct scale of magnitudes. For this purpose, very faint standard sequences have been established with the photon counter in three of the Kapteyn selected areas. W. Baade has already used these sequences, along with a revised Cepheid zero point, to estimate a new modulus for the Andromeda galaxy of 24.2 magnitudes, corresponding to a distance of about two million light-years. This result has been tentatively confirmed by direct photoelectric observations of red giants in the southeast halo of that galaxy, including the star for which counts are given in Fig. 10.

The counter has also yielded an important result bearing on stellar populations. It has shown that the main sequences of globular clusters are comprised of subdwarfs. This was discovered from the photometry of faint stars in Messier 13 (featured in the center of this issue), and it has now been confirmed in Messier 3. Further work on other clusters is in progress. The result apparently means that the familiar main sequence for stars in the solar neighborhood is only a particular case lying near one edge of a main-sequence band embracing dwarfs and subdwarfs together.



This chart of M13 is from a 200-inch photograph, and can be used as a key to the feature picture on the following pages. Numbers identify stars measured photoelectrically by Dr. Baum. The yellow magnitudes for the numbers included on the chart are: 1, 10.74; 2, 12.03; 3, 12.04; 4, 12.14; 5, 12.15; 6, 12.43; 7, 12.64; 8, 12.81; 9, 12.85; 10, 13.14; 11, 13.28; 12, 13.46; 13, 13.49; 14, 14.50; 15, 14.84; 16, 15.01; 17, 15.07; 18, 15.47; 20, 16.05; 21, 16.10; 22, 17.03; 25, 17.86; 26, 17.99; 27, 18.33; 32, 21.14; 33, 21.40. The marks at the edges represent minutes of arc. Adapted from the "Astronomical Journal."

ASTRONOMICAL SCRAPBOOK

Other Satellites of the Earth

ONE of the most famous meteoric phenomena on record happened on February 9, 1913. This was long believed to have been a procession of about 50 fireballs, moving very slowly from horizon to horizon in nearly the same path, seen from western Canada, across Minnesota, Ohio, New Jersey, and Bermuda to the equator—a distance of over 5,600 miles.

It was, however, established by C. C. Wylie in 1939 that these widely spaced observers had not viewed the same meteors, so what really occurred was an intense but ordinary meteor shower rather than a true meteoric procession.

Even so, there are some interesting consequences of the original idea of a procession of meteors. For if the course and velocity with which such bodies approach the earth were favorable, they could be captured as satellites, circling far enough above the earth's surface to avoid destruction by the atmosphere—the fate of all ordinary meteors. They would then be the type of body looked for in C. W. Tombaugh's intensive photographic search now under way at the Lowell Observatory. His is the first sustained effort, with modern optics and careful programming, to discover additional satellites of the earth.

How a hypothetical satellite would appear to an observer was discussed in detail by W. H. Pickering in 1923. He showed that a meteorite one foot in diameter, revolving in an orbit 200 miles above the earth's surface, could be as bright as 10th magnitude at times, shining by reflected sunlight. It would resemble an unusually slow-moving telescopic meteor. Objects of this sort may well be picked up in Tombaugh's search.

Controversy about earth satellites dates back at least to 1821. The British meteorologist, John Farey, held that many meteors were small terrestrial satellites traveling in eccentric orbits, dipping deep into the earth's atmosphere at every perigee passage. This view was rebutted by Dr. William Burney, of Gosport, England. Nevertheless, the idea lingered, and in 1867 the British amateur, W. E. Hickson, argues for their existence. You can find a meteoric satellite in science fiction as early as Jules Verne's *From the Earth to the Moon* (1865).

Is it possible that a meteoric satellite has already been observed? The unfounded report of last August is explained in last December's *Sky and Telescope*, page 51. There was rather more justification for the momentary suspicion that one had been found in 1938, but the rapidly moving object discovered on Koenigstuhl Observatory photographs turned out to be a new asteroid, Hermes, passing within 440,000 miles of the earth.

There is, nevertheless, a classic case where the discovery was reported by a

(Continued on page 354)

Amateur Astronomers

Southeast Convention Held in Decatur

DURING perfect weather the convention of the Southeast Region of the Astronomical League was held on April 16-17 at Bradley Observatory in Decatur, Ga.

The subjects presented were varied. "Stellar Populations I and II" were described by Dr. Kenneth M. Yoss, Louisiana State University. "The Snooperscope in Astronomy" was the topic of a talk by William E. Shawcross, of Chapel Hill, N. C., and a portable photoelectric gadget was demonstrated by Dr. W. A. Calder, our host astronomer.

Trips having astronomical objectives were described by several people. Dr. Karel Hujer, University of Chattanooga, presented outstanding slides and a colorful description of observatories and astronomers visited on his way through England and western Europe to Scandinavia, where he saw the eclipse of June, 1954. Highlights of the Princeton meeting of the American Astronomical Society were presented by Dr. Yoss.

Representatives of 12 societies attended from five states of the region. Reports of the activities of 11 of these groups were given. New regional officers were elected: chairman, Dr. Robert E. Angell, St. Petersburg, Fla.; vice-chairman, Arthur H. Jones, Chattanooga, Tenn.; secretary, Otto Borman, Eau Gallie, Fla.; treasurer, Harry Johnson, Atlanta, Ga.

The undersigned spoke about the Astronomical League's coming convention at Seattle, while members of two Florida societies described plans for the 1956 general convention in Miami. Next year the Southeast convention will be held in conjunction with that event.

C. H. HOLTON
833 Drewry St. N. E.
Atlanta, Ga.

Northeast Regional Convention in Troy

A DOZEN societies in the Northeast Region of the Astronomical League were represented by some 75 amateurs who attended the convention at Troy, N. Y., on April 21-22. Among them were many junior astronomers, and four papers by juniors were presented.

Visitors were brought up to date on some of the past and present activities in the Albany-Troy-Schenectady area by several talks. One of these was the history of the Dudley Observatory, by Paris Cenni, of Troy; another described the growth of astronomy at Rensselaer Polytechnic Institute, and was given by Prof. G. Howard Carragan, head of the physics department. The RPI Observatory had its beginnings in the desire of a freshman student of the late '30's to complete his telescope mirror; students at this engineering school furnished the designs and the know-how to plan a building that now houses a 12-inch reflector.

Recent developments in the program of the American Association of Variable Star Observers were presented by Clinton B. Ford, AAVSO secretary; he stressed the increasing application by amateurs of photoelectric photometry to variable star and other observing work. Four AAVSO members now have or are procuring photoelectric equipment. One of these, J. J. Ruiz, of Dannemora, N. Y., demonstrated his own apparatus. He used an eclipsing binary model to produce a variable light source, recording its light curve on the spot. He was able to demonstrate the reflection effect and the change in secondary minimum position with change in orbital eccentricity.

A half-hour color motion picture, Project Eclipse, with taped sound was presented by W. L. Hollingsworth, Rochester, N. Y., who was in Iceland in June, 1954, as a member of one of the Air Force-Georgetown University observing teams. Totality was observed through a large hole in the clouds.

At the banquet, Dr. Robert Fleischer, RPI astronomer, spoke on "A Two-inch Grain of Dust." He explained the problem of dust and gas in the Milky Way, and said that RPI scientists planned to study the effects of "dust" models of various shapes and sizes by means of microwaves; some of these models will be two inches in length.

New officers for the Northeast Region are: chairman, Mr. Cenni; vice-chairman, Russell Edwards, Schenectady, N. Y.; secretary, James Kaler, Albany, N. Y.; and treasurer, John E. Welch, Springfield, Mass. (re-elected).

H. S. F.

BLAIR MEDAL AWARD AT WESTERN CONVENTION

Walter H. Haas, Las Cruces, N. M., director of the Association of Lunar and Planetary Observers, has been chosen by the Western Amateur Astronomers to receive the 1955 G. Bruce Blair medal for notable achievement in furthering amateur astronomy.

Presentation of the medal will be a feature of the banquet at the WAA seventh annual convention, to be held in Yosemite National Park in California, on August 19-21.

Another highlight of the convention will be the star party, to be held at the Badger Pass ski area at an altitude of over 7,000 feet. This will give excellent opportunity for testing telescopes in the clear air of the High Sierras.

Those who wish to receive further information about the convention should write Mrs. Arthur S. Leonard, 815 Douglass Ave., Davis, Calif. Advance registration of $2.25 may be sent to John E. Gabrian, 1917 Bristol Ave., Stockton, Calif., with remittance payable to the WAA Convention Committee.

Camp Curry will be convention headquarters, where the meeting room, exhibit hall, and dining room will be located. The convention opens Thursday evening, August 18th, with a public observing session at the campfire program on the floor of Yosemite Valley near Camp Curry, for which the host societies will provide telescopes. The banquet will be on the following evening.

CARL W. ANDERSON
Convention chairman
2581 Avalon Drive
Sacramento 21, Calif.

THIS MONTH'S MEETINGS

Kalamazoo, Mich.: Kalamazoo Amateur Astronomical Association, 8 p.m., home of Mr. and Mrs. Jerome Korman, 2319 Fairfield Rd. June 18, Dick East, "Comets"; Keith Peterson, "Asteroids"; Phil Steffey, "Life on Other Worlds."

St. Louis, Mo.: St. Louis Amateur Astronomical Society, 8 p.m., St. Louis Institute of Technology. June 17, Dr. James Boyd, Monsanto Corp., "Treasures of Scorpius."

South Bend, Ind.: St. Joseph Valley Astronomers, 7:30 p.m., YMCA. June 2, John Urednick, "Light."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. June 4, Dr. E. Wyllys Andrews, Tulane University, "Astronomy of the Ancient Mayas of Central America."

STELLAFANE—AUGUST 20th

The 1955 Stellafane meeting will take place at Springfield, Vt., on August 20th. The moon will be three days old, and good seeing is "96 per cent" predicted. Joint hosts are the Springfield Telescope Makers and the Amateur Telescope Makers of Boston.

This traditional meeting at the original mecca of amateur telescope makers was reactivated in 1954 after a lapse of some years. All interested persons are invited. No open fires will be permitted, but approved outdoor cooking stoves may be used, or picnic meals may be brought. The gathering begins informally during the afternoon and continues into the night.

Room reservations, if desired, can be made through the Hartness House, Springfield, Vt.

JAMES W. GAGAN
ATM's of Boston
Harvard College Observatory
Cambridge 38, Mass.

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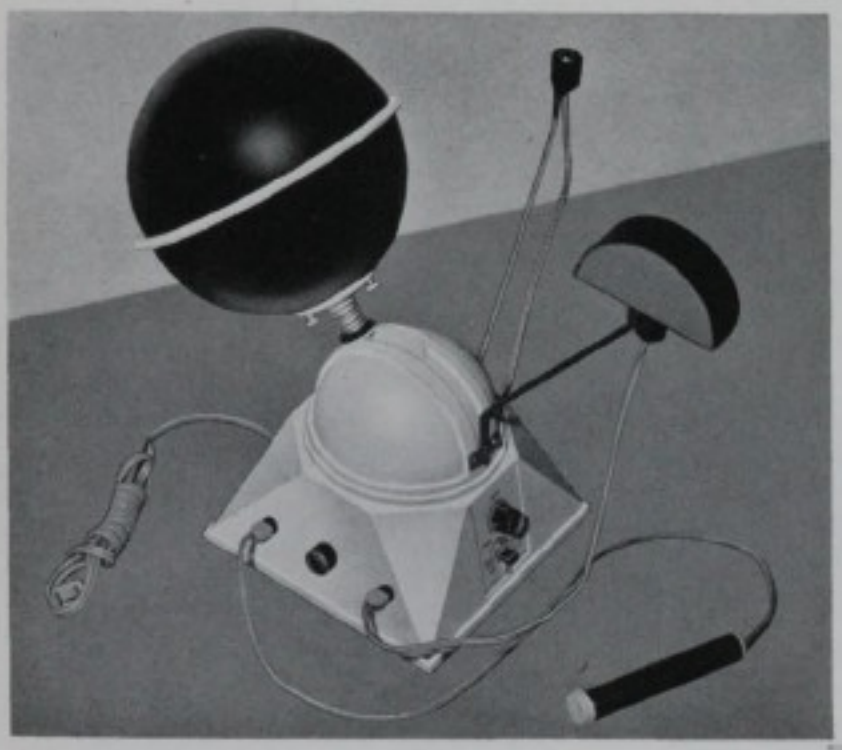

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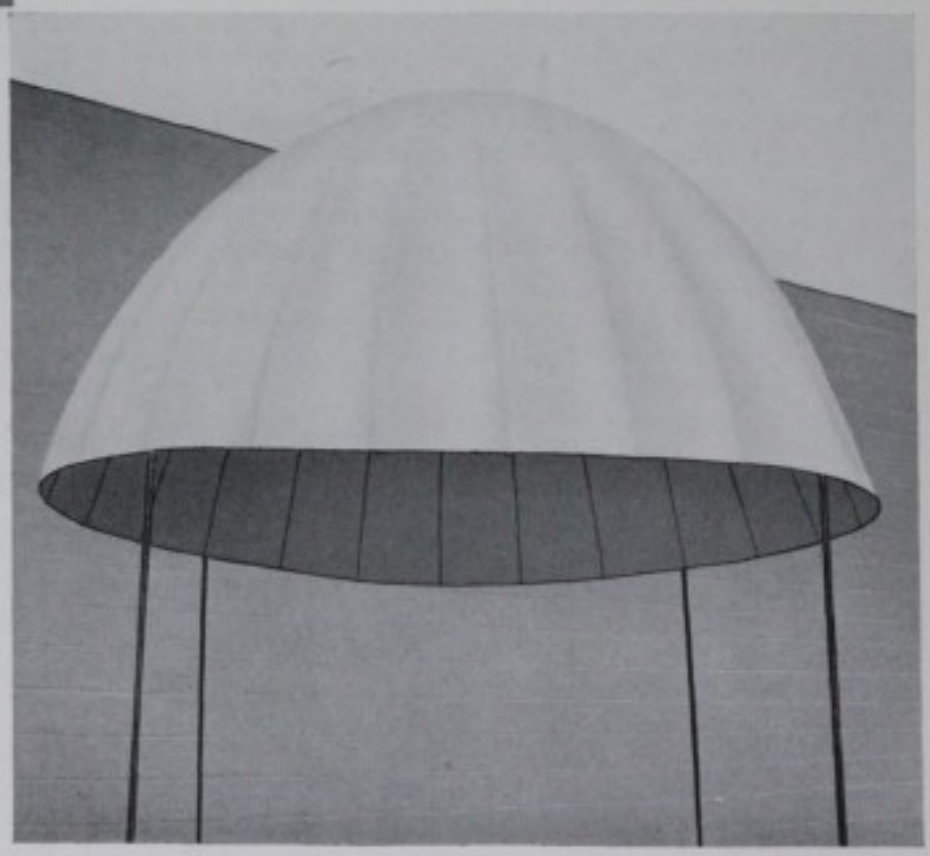

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BOOKS AND THE SKY

EXPLORING MARS

Robert S. Richardson. McGraw-Hill Book Co., Inc., New York, 1954. 261 pages. $4.00.

DESIGNED primarily for the general reader, this interesting volume not only covers the planet Mars but gives information on the other planets in our solar system. It also contains some discussion of space flight.

The book divides into three main parts, the first consisting of Chapters 1 to 5. The first accurate observations of Mars, by Tycho Brahe, are described, as is their analysis by Johannes Kepler. At this point there is a very readable account of Kepler's laws of planetary motion. There is a chapter on the possibility of space flight, the elements of rocketry, and an imagined flight to the moon. Next, in 13 informative pages we find discussions of the possibility of a lunar observatory, lunar meteorites, the theories of lunar crater formation, and remarks concerning time on the moon. Chapter 5 takes us on our trip to Mars and gives further attention to rockets and space flight.

The second division (Chapters 6 to 10) covers the main topic of the book, Mars itself. A perpetual calendar for Mars is given. In the material on the Martian atmosphere, we learn of the spectroscope and what its use has revealed about Mars. Polar caps, composition of the atmosphere, and the temperatures on the red planet are all discussed.

In Chapter 8 is one of the most interesting parts of the book, a discussion of the possibility of life on Mars. Some of the absorbing thoughts presented include that of the meteorologist, Seymour L. Hess, concerning the behavior of possible areas of vegetation during and after the blue clearing. Dr. Richardson writes:

"If there is vegetation on Mars, it presumably would be damaged by exposure to ultraviolet light, since normally it is shielded by the blue mist. But when, on rare occasions, the blue mist clears away, the surface is directly exposed to these rays, and the vegetation would be severely damaged. If this is the case, then the dark regions over which the clearing occurred should later exhibit an abnormal change in tint, because of the death of plant life there."

We are then brought to the canal question, on which Dr. Richardson comments, "Apparently the most critical factor favoring visibility of the canals is not the size of the telescope or a special kind of eye but the quality of the seeing." This statement will probably be agreed to by the majority of experienced planetary observers. The last section of Chapter 9 is devoted to the moons of Mars.

Next, for the beginner in astronomy or those who lack telescopic equipment, the author tells how to locate Mars with the naked eye and how to follow its path among the stars. Charts for identifying the planet are given for 1955 and the coming close opposition year of 1956.

The third part takes up the other members of our sun's system of planets. The highly readable chapters give good pictures of these worlds in the light of present-day knowledge.

One might wish that more of the volume had been devoted to the title subject, and that the advertised maps had actually been included. Among the illustrations and charts, the planetary photographs are large and well reproduced.

This book can be recommended to those interested in Mars and especially to beginners in astronomy for introductory material on the solar system. It is written in an easily understood and entertaining manner.

D. P. AVIGLIANO
Mars Recorder
Association of Lunar
and Planetary Observers

THE MATHEMATICAL PRACTITIONERS OF TUDOR AND STUART ENGLAND

E. G. R. Taylor. Cambridge University Press, New York, 1954. 443 pages. $9.50.

HERE is what must surely be the most complete study available of the great men and small, "teachers, textbook writers, technicians, craftsmen," who worked with mathematics and astronomy between the years 1485 and 1715. The author gives an impressive example of research and scholarship, just as in her earlier works on Tudor and early Stuart geography (1930 and 1934).

Divided into three sections, narrative, biographical notes, and bibliographical notes of the works of the practitioners, this volume is hardly intended for the casual reader. The last two sections (almost two thirds of the book) are frankly presented as reference material for the historian of science. The first section contains so much material on so many people, in such a compressed chronological framework, that any but the most careful reader is apt to be overwhelmed in detail.

The person who takes his history of science seriously should welcome this book. It is a notable addition to the reference material covering a period of English science that has been too little studied, and though the title refers to "mathematical practitioners," the astronomer will find much here to interest him.

The earlier work of the author, and Francis R. Johnson's *Astronomical Thought in Renaissance England* (1937), have made it clear that the description of English science given us by Francis Bacon is less than adequate. For astronomers,

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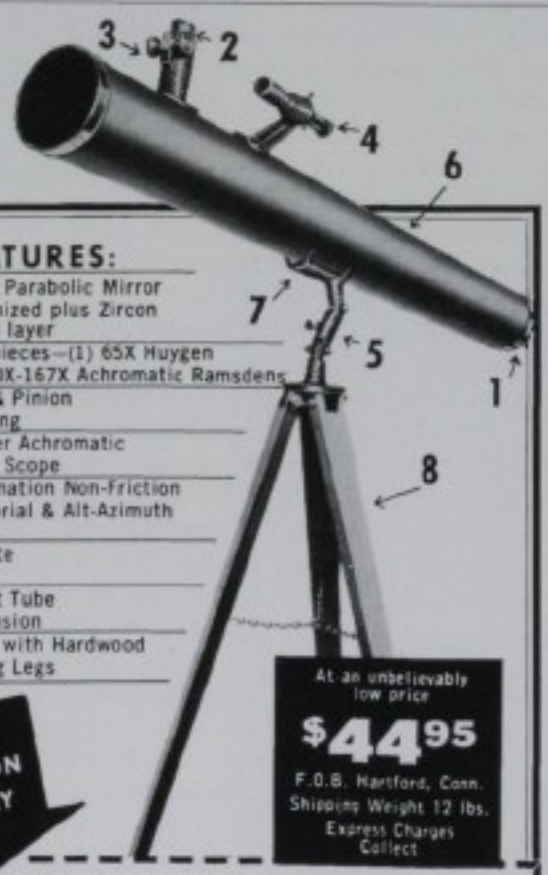

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the present book will fill out the detail in Johnson's picture and show the other side of the scientific work of such men as John Dee, Leonard and Thomas Digges, and Thomas Harriott; it also describes the more practical aspects of the endeavors of men like Robert Norman, William Gilbert, Henry Briggs, Isaac Newton, and John Flamsteed. The greater emphasis of the book, however, is on the many men hardly known in their own day and not at all familiar to us today, who taught, wrote books, and made instruments: the men "but for whom great scientists would always remain sterile in their generation."

What structure the narrative has is supplied by the centrality of the interest in navigation. The author gives convincing evidence that this emphasis on navigational subjects is not misplaced. The strongest single motivation of the mathematical practitioners, whether they were astronomers, or instrument makers, or teachers and writers, seems to have been the problems associated with navigation. It is not surprising that this book has been published for the Institute of Navigation. The amateur astronomer who chooses to read it will profit most, perhaps, in an increased awareness of the practical significance of the astronomical work which was done during the period discussed.

Unfortunately, the arrangement of the material gives the untrained reader few hints as to which of the developments are the most significant. The account of a relatively minor improvement of a surveying instrument may follow directly upon that of invention of the slide rule. For a reference book this is not a handicap, and the indexing and cross references are excellent. But the general, interested reader will have to wait until someone—Professor Taylor, one hopes—rearranges the material, assesses its significance, and presents a less detailed but more judicial account of the work done in this period.

ROBERT E. SCHOFIELD
Harvard University

NEW WORLD PLANISPHERE

Kingsland Camp. Louise Brandwein, Fenimore Rd. and Cornell St., Scarsdale, N. Y., 1953. $10.00.

PLANISPHERES have their advantages and disadvantages, as constellation students well know. But in this well-constructed "instrument" a new principle has been applied that does away with one of the chief faults of the ordinary planisphere—very small scale and excessive expansion of constellations along the horizon opposite to that of the observer's pole.

The basic element of a planisphere is a star chart centered on one of the poles of the sky; this chart is on a disk that revolves beneath an overlay cut out to show only the part of the sky above the horizon at any one time. The chart disk is revolved into position to correspond to the date and time of observing, so the proper stars are visible.

Not only does a planisphere tell what stars are above one's horizon, and in what directions, but it may be used to ascertain how soon a particular star or group will rise or set. Usually, the shape of the cut-out restricts the observer to one latitude, say 40° north for planispheres ordinarily available in the United States. Some constellations visible from latitude 25° north would not even be included on the chart of a 40° north planisphere, but the New World Planisphere does not have this restriction, and may be used anywhere.

The pole-equator distance is 9 centimeters, which sets the scale of the charts. On the northern side, however, the outer edge is at −20° declination instead of at −50° as it would be in an ordinary 40° north planisphere. The distortion of that extra 30 degrees is avoided, and the user must turn to the southern side for stars down to his southern horizon. Here Orion, Lepus, Columba, and groups with similar declinations are represented nearly as well as on a stereographic projection.

For much of the northern sky, then, the northern side is used; for southerly objects and the horizon at the east and west points, the southern side of the chart is used.

The charts are on a stiff plastic disk:

UNITRON Accessories . . . Including a Progress Report on New Items

Interim Report

At the beginning of this year in our report, "Prevues for 1955" (**Sky and Telescope**, January and February, 1955), we briefly introduced some of the new UNITRON instruments and accessories. Now we bring you up to date on the progress made on some of them, and remind you of the UNITRON accessories which have already won many friends. You will find it helpful to refer frequently to the outside back cover which illustrates most of the items discussed.

The Astro-Camera

Photography and astronomy go hand in hand, and this newest UNITRON accessory — Astro-Camera 220 — can add a new dimension to your observing program. Model 220 uses the telescope objective as the camera lens and fits every UNITRON (with the exception of the 1.6" model).

Owners of altazimuth models can photograph the sun, sunspots, the moon, and solar and lunar eclipses. An equatorial model is required for recording other celestial objects which need longer exposures, and the clock drive is essential for prolonged tracking. The camera uses an air-operated curtain shutter of the Thornton-Pickard type, giving speeds of 1/10 to 1/90 second in addition to bulb and time. The 36.8-mm. O.D. tube of the camera inserts into the UNITRON rack-and-pinion sleeve, replacing the drawtube. The camera may be positioned so that the plane of the film passes through the focal point of the objective, which is then the only optical element. When magnification of the primary image is desired, an eyepiece can be inserted into the camera tube and an image projected on the film. Astro-Camera 220 comes complete with ground-glass back, 3 double plateholders for 3¼" x 4¼" plates or cut film, a 30-mm. f.l. eyepiece, extension tubes and clamps, and a fitted wooden cabinet. The camera is priced at **$69.50 complete** and will be ready for delivery in about 60 days.

UNIHEX Rotary Eyepiece Selector

It is unlikely that there exists a **Sky and Telescope** reader who hasn't heard of UNITRON's new rotary eyepiece selector.

Any of the 6 eyepieces may be instantly rotated into position to provide the magnification appropriate to the subject and observing conditions. UNITRON owners who have bought UNIHEX tell us that they wouldn't part with it for any amount of money. We, however, will part with one for **$24.75**, for which sum we include a wooden cabinet and pay the postage. The model offered until now has been labeled Model A, and is designed to fit the UNITRON rack-and-pinion sleeve in exactly the same manner as described above for the camera tube. Recently we were petitioned to provide the blessings of UNIHEX for owners of all makes of telescopes. Therefore, we offer Model B, fitted with 1¼" O.D. tubing. This slips into your eyepiece holder and is fastened with an ingenious clamp. UNIHEX-B will hold up to 6 of your 1¼" O.D. eyepieces. Plastic plugs are provided to keep out the dust if fewer eyepieces are used. Both models are available now — please specify either Model A or B when ordering.

A Trio of View Finders

These are old friends to ATM's. Many an instrument has been given a finishing touch in the way of utility and appearance by adding one of these precision finder scopes. All three models naturally have achromatic objectives (air-spaced in the 42-mm. model), crosshair eyepieces, and come complete with mounting brackets and centering screws for collimation. Postpaid prices are **$8.50** for the 6x 23.5-mm., **$10.75** for the 8x 30-mm., and **$18.00** for the giant (15" long) 10x 42-mm. model. (Illustrated on this page.)

UNICLAMP Accessory Brackets

This is an accessory we have just developed so you can add new UNITRON gadgets to your telescope **without** drilling holes in the body tube. Looking carefully at the back cover, you will notice that the brackets of the guide telescope are not attached to the tube itself but are screwed into two black brackets that encircle the tube.

These black brackets are UNICLAMPS. They are hinged at one end and, together with any attached accessory, can be installed on or removed from the tube in a jiffy. UNICLAMPS will be offered in sizes to fit our 2.4", 3", 4", and our forthcoming 6" refractors. With UNICLAMPS, guide telescopes, large view finders, sunscreen apparatus, counterweight assemblies, and the like can easily be added to those UNITRON models that lack this equipment. It will now be easier than ever to keep your UNITRON up to date and to add accessories as you feel the need for them.

2.4" Guide Telescope

We have really been surprised at the number of observers, intrigued by its relatively short focal length (700 mm.) and consequent portability, who choose this guide telescope for general observation in preference to our regular f/15 refractors.

Adding the guide telescope to your 3" or 4" UNITRON is also a way to permit two people to observe simultaneously. With the star diagonal you may, of course, direct the light in any convenient direction so that heads need not bump. Just picture the possibilities—father looks through the main scope, mother through the guide telescope, and baby through the view finder (apologies to the "Three Bears"). The UNITRON 2.4" Guide Telescope has a coated, air-spaced objective, rack-and-pinion focusing, and comes with star diagonal, mounting brackets, and wooden cabinet for **$75.** An achromatized symmetrical 9-mm. crosshair eyepiece is furnished as standard equipment, although any of the UNITRON eyepieces may be used.

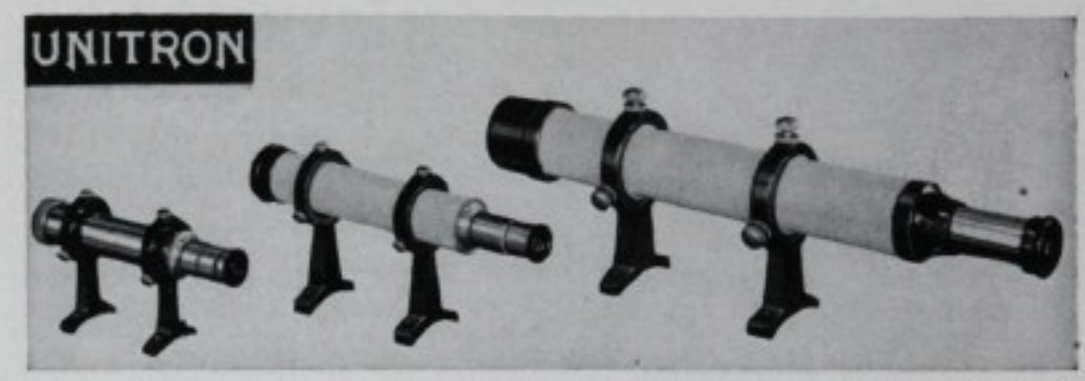
Sun Projecting Screens

It's interesting to watch the changing appearance of the solar surface from day to day, and many amateurs keep careful records of genuine scientific value. One of the most interesting ways to observe phenomena such as sunspots, and one that is ideal for group viewing, is with a sun projecting screen.

Until now we have offered two sizes: 6" x 6" (as supplied with our 3" models) at **$13.50 postpaid**, and 7" x 7" (as supplied with our 4" models) at **$15.75 postpaid**. Now a new model especially designed for the UNITRON 2.4" models has been scheduled for production; its price will be announced next month. UNITRON owners will easily be able to install the sunscreen set using the UNICLAMP brackets, in about the time it takes to say "filamentary structure of spot penumbrae."

Objectives and Eyepieces

If you have a refractor that is satisfactory in all respects but the lens, give it a new lease on life, with a UNITRON objective. The superb performance of these lenses is, of course, the basic factor in our reputation for fine quality. UNITRON objectives are air-spaced coated achromats and come mounted in a cell. Prices are **$35** for the 2.4", **$69** for the 3", and **$135** for the 4". We can also supply at slight additional cost a second holder for the objective cell itself. This holder comes with a dewcap and is ready to attach to the body tube. Our eyepieces can, of course, be used with any type of telescope. They are currently available in focal lengths from 6 to 60 millimeters. All UNITRON optics have been designed expressly for astronomical observation. We do not have any surplus optics from the War of 1812 (or any other conflict), designed for observing the enemy at close range.



L. to R.: (1) 23.5-mm. 6x finder; (2) 30-mm. 8x finder; (3) 42-mm. 10x finder

Equatorial Mountings

The UNITRON equatorial mountings are available separately for those who have a good telescope but an inadequate mount. The mounting supplied with our 3" Equatorial is priced at **$198**, complete with field tripod and cabinets. The mounting used on our 4" (illustrated on the back cover) is priced at **$370**, complete with field tripod and cabinets. These mountings are oversized and can easily support larger instruments.

Clock Drives

Our first clock drive to be offered will be the weight-driven model illustrated with the 4" pier on the back cover. This type may also be used with the wooden field tripod. It requires no electric current and is, therefore, quite handy for portable instruments and in locations where stringing a wire would be a nuisance. It's fun to watch the spinning governor through the Plexiglas window. An alternative drive, using a synchronous motor, is now in the testing stage and will be offered for the 4", 3", **and even the 2.4" Equatorials.**

Design for the Future

We have described above some of the UNITRON accessories that either are already available or soon will make their appearance. Others are now in the design stage and will be introduced at a later date. A few, such as the super-secret UNIZOR, cannot be discussed at this time. All UNITRON accessories are standard equipment in UNITRON refractors themselves and, therefore, show the results of our preoccupation with perfection. UNITRONS are not gadgets and not toys. Neither are they assembled from odds and ends. They are products of a serious, forward-looking manufacturing program. That is why when you buy a UNITRON you invest in the telescope of today and tomorrow.

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See page 347 and the back cover.

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Air-spaced Achromatic Objective (uncoated) ..... **$28.00** postpaid

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54 mm (2⅛")	508 mm (20").....	**12.50**	83 mm (3¼")	762 mm (30").....	**28.00**
54 mm (2⅛")	600 mm (23⅝")...	**12.50**	83 mm (3¼")	876 mm (34½")...	**28.00**
54 mm (2⅛")	762 mm (30").....	**12.50**	83 mm (3¼")	1016 mm (40").....	**30.00**
54 mm (2⅛")	1016 mm (40")....	**12.50**	110 mm (4⅜")*	1069 mm (42 1/16")	**60.00**
78 mm (3 1/16")	381 mm (15").....	**21.00**	110 mm (4⅜")	1069 mm (42 1/16")	**67.00**

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Known among amateurs as the "Giant Jaegers," this is the finest wide-angle eyepiece ever made. It gives a flat field. It is mounted in a focusing cell. This is an Erfle eyepiece, 1½" effective focal length, with a clear aperture of 2 3/16". It may be used as a Kodachrome viewer, magnifying seven times.

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16 mm (⅝") F.L. triplet eyepiece contains a three-element lens and a simple lens.
Coated lenses **$13.50** Not coated **$12.50**

18 mm (¾") F.L. symmetrical eyepiece contains two cemented achromats.
Coated lenses **$6.75** Not coated **$6.00**

22 mm (27/32") F.L. Kellner eyepiece contains cemented achromat and a non-achromatic lens.
Coated lenses **$6.75** Not coated **$6.00**

32 mm (1¼") F.L. eyepiece contains two achromatic lenses.
Coated lenses **$13.50** Not coated **$12.50**

35 mm (1⅜") F.L. symmetrical eyepiece contains two cemented achromats.
Coated lenses **$8.75** Not coated **$8.00**

55 mm (2 3/16") F.L. Kellner eyepiece contains achromatic field lens and a non-achromatic eye lens.
Coated lenses **$6.75** Not coated **$6.00**

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the overlays are also plastic, with white outer portions on which dates are printed in red. The transparent portion of each overlay is circular, the full size of the disks, so that *all* of the chart may be seen at one time. That part below the horizon for 40° north is a transparent green. Thus, stars below as well as above the horizon may be identified.

Calendar reform advocates will be pleased to find that the World Calendar is used for this chart. At most, the difference between its dates and ordinary calendar dates is a few days, and this is no more serious a discrepancy than might be the observer's difference of longitude from a standard meridian or difference of latitude from 40° north.

For use in other latitudes, masks of paper are provided that may be cut out and pasted over the proper portions of each overlay, but the charts do not then have the advantage of the transparent green plastic. Nevertheless, they render the planisphere convertible to any latitude. This same purpose could be served by scoring or marking the overlay plastic, to retain the visibility of each entire chart.

The accuracy of the representation of the constellations appears to be very good; printing is clear and legible, with the Milky Way shown, as well as the ecliptic and equator and the circle of precession of the poles. Greek letters are given for all stars to magnitude 3.5, and some stars to 5th magnitude are plotted. Interesting telescopic clusters and nebulae are indicated. No scales of right ascension appear except around the periphery of each chart, and there are no declination scales at all—the meridian might well have been marked for this purpose.

The planisphere is well manufactured and sturdy, but it cannot be taken apart to clean dirt from between the overlays and the charts. Grit caught between these faces will score the overlays in a circular pattern and eventually mar its transparency. Provision for separating the disks should be made. Serious as this fault may be, this is the finest planisphere the writer has used. C. A. F.

NEW BOOKS RECEIVED

BERKELEY CONFERENCE NOTES, 1954, *Robert Fleischer*, editor, 1955, *Observatory of Rensselaer Polytechnic Institute*, 265 pages, paper bound. No charge.

These are lecture notes of a conference for astronomy teachers, held August 12—September 8, 1954, at Berkeley, Calif., under the joint sponsorship of the University of California and the National Science Foundation. The 57 lectures, by 29 experts, give technical summaries and bibliographies of topics from radio astronomy to asteroid perturbations, from stellar atmospheres to cosmic rays.

A few copies of this publication are available for distribution, especially to teachers of astronomy who have limited contact with other astronomers. Requests should be addressed to Dr. Robert Fleischer, RPI Observatory, Troy, N. Y.

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Every instrument, with its ¼-wave, aluminized mirror, is individually tested before being packed for shipment. We suggest that before buying you inquire at almost any local astronomy society about the efficiency of Skyscope. *100% American-made.*

We invite your attention to our free and straightforward descriptive brochure which also shows a photograph of the individual parts used.

125-power and 35-power extra eyepieces	$5.15 each
Six-power finder, with brackets	$7.50
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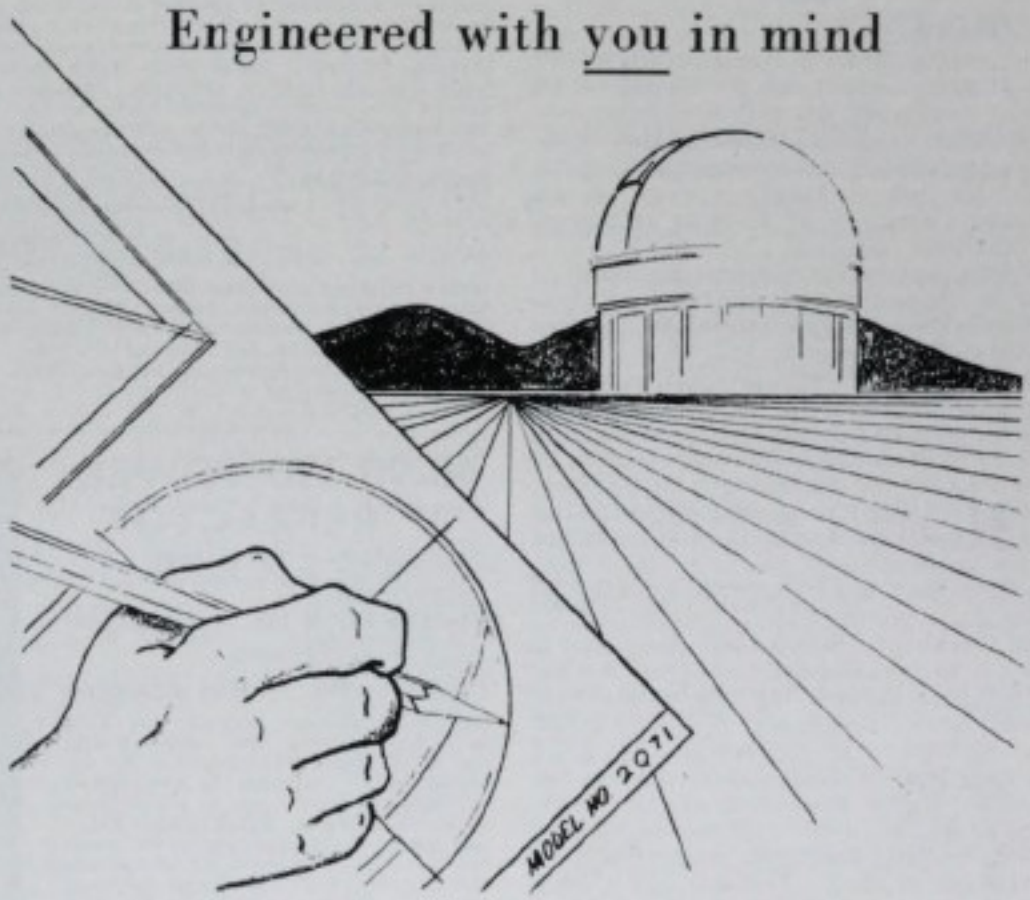


Place your confidence in ASTRO-DOME

Your observatory will be engineered to fit your space requirements. If an old dome is to be replaced, ASTRO-DOME will design the new dome to fit the area vacated by the old structure. Perhaps you have a problem in locating a suitable site. We will be glad to show you examples of installations and cite specific instances where installation problems were solved.

Whether you buy a small or large observatory, we have your needs in mind and we will fill your exact requirements.

ASTRO-DOME MANUFACTURING, INC.

1800-06 Wallace Ave., N.E.; Box 127, Sta. A; Canton 5, Ohio

Telephone: GLendale 3-2142

WHAT'S NEW AT EDMUND'S

by Norman W. Edmund

Dear Fellows:

The missing link has been added to our line—a sturdy mount for 6" telescopes. In the last few years we added mirrors, eyepieces, tubes, eyepiece rack-and-pinion holders, spiders, finders, mirror mounts, and tripods. Now that our mount is ready, we can also offer a complete 6" scope as well as all the individual parts.

We make our mount so you can attach it either to a tripod or a permanent post in the ground. It's made sturdy enough so that you can use an 8" scope on it.

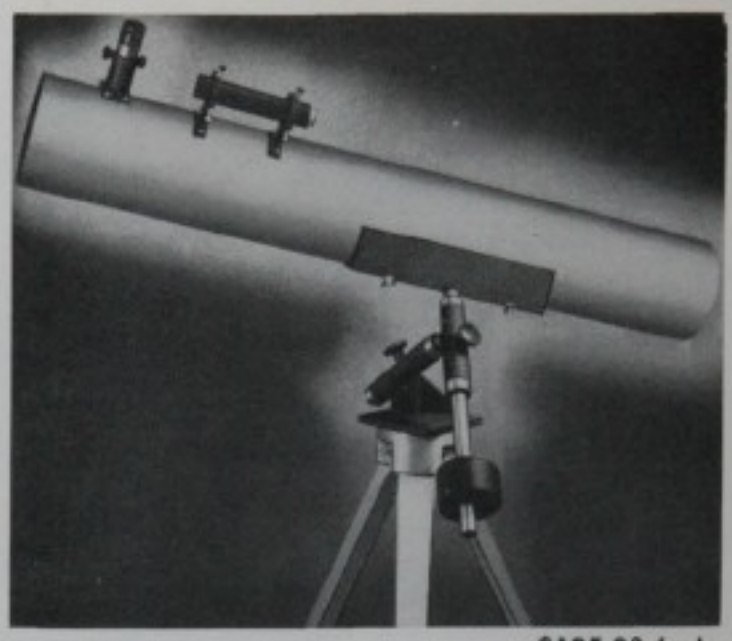
Our complete 6" reflector is a very nice looking job. Something anyone would be proud to own and proud of its performance. The tube is black inside but white outside so you don't have trouble seeing it in the dark. It's made of plastic impregnated fibre—more expensive than an aluminum tube but superior for a telescope of this size. Its 6-inch, 48-inch, mirror is of excellent quality. So we are quite proud of it.

Last month I mentioned we would have a refractor rack-and-pinion eyepiece holder. While it was finished too late to illustrate in this month's advertising, it is now ready. Has a 4¼" travel so that you can use it for close-up terrestrial viewing. It's a beauty, too —chrome plated and black crinkle finish. Priced at $12.95, it is Stock No. 50,103-Y.

We now have the latest model Spitz Jr. Planetarium in stock. This one has a little pointer with it that plugs into a small transformer on the side of the base. Price is still the same in spite of this improvement. Do you already own a Spitz Jr. Planetarium? If so, check and see if the globe is held on with three thumb screws.

If so, it can be removed and a globe with the southern hemisphere stars attached. This globe costs only $3.98, order our Stock No. 70,060-Y. More interesting and fascinating, though, is the "Sky Zoo" globe. This projects silhouettes of mythological figures. Order Stock No. 70,059-Y at $3.98. Or if you want a new model planetarium with a Sky Zoo globe on it so that you can superimpose the Sky Zoo figures on the actual constellations projected by a regular globe, then order Stock No. 70,058-Y. Price, $14.95. This new Sky Zoo globe adds a lot of novelty and will be of special interest to schools and astronomical clubs presenting group showings.

6" REFLECTING TELESCOPE



Complete with heavy duty equatorial mounting and tripod. Tripod has cast aluminum head and rugged wooden legs for stability. (Folds for storage.) Equatorial mount has 1" diameter shafts with Boston bronze bearings. 5-lb. counterweight for perfect balance. Locks on both declination and polar axis. Polar axis set at 40°; latitude adjustment made with tripod legs. Black crinkle finish on mount. Telescope tube made from plastic impregnated fibre. White enamel finish on outside. Rack-and-pinion focusing eyepiece mount. 7X achromatic finder with crossline reticle. 6" Pyrex mirror—48" F.L. (f/8)—aluminized and overcoated—guaranteed to give theoretical limit of resolution. Mirror mount machined cast aluminum. Combination eyepiece gives 60X and 120X. Extra eyepiece available for 200X.

Stock #85,024-Y ..... **$195.00 f.o.b.**

3" REFLECTOR ASTRONOMICAL TELESCOPE KIT

Complete parts—no machining—easily assembled; a nine-year-old can do it! All nuts and bolts supplied. Nothing extra to buy. Kit includes 3" spherical mirror 30" F.L., aluminized and overcoated. Guaranteed to resolve detail right up to theoretical limit. Tripod 40" high with cast-iron tripod head, all holes drilled and tapped (all machining finished). Other parts made from ⅛" thick steel all ready to assemble. Smoothly functioning altazimuth mounting. Locks on both polar and declination axes. Polar axis at 40°; latitude adjustment made with tripod legs. Natural grain finished hardwood tripod legs. Heavy 3/16"-wall kraft telescope tube with special black glare-reducing liner. Eyepiece mount has slide focus adjustment. Mirror attaches on new type mounting with pressure-sensitive adhesive tape eliminating distortions. Mirror is ventilated. 60X eyepiece included. 90X and 120X eyepieces available at extra cost. Crosshair finder parts included with mountings. Parts zinc plated to prevent rust. A real kit in every respect. Can also be used terrestrially. Nothing extra to buy. Money back guarantee.

Stock #85,025-Y ..... **$29.50 f.o.b.**

6" & 8" EQUATORIAL MOUNT

Heavy ⅜" steel plate base with five ½" holes for attaching to your post or tripod. Welded construction throughout. One-inch shaft with Boston bronze bearings. Bearings and housing 6" long. 5-lb. counterweight for balance on 16"-long shaft. 1¾" diameter locking knobs on both declination and polar-axis shaft. Polar axis set at 40°; latitude adjustment made with tripod legs. 14" cradle securely holds from 4" to 10" diam. telescope tubes. Mount weighs 27 lbs. and is approximately 14" high.

Stock #85,023-Y ..... **$49.50 f.o.b.**

40-90-190 POWER 3" REFRACTOR TELESCOPE

Complete With Equatorial Mount, Tripod and Prism Finder!

Here's a telescope bargain you have never seen before. This telescope uses the 3" objective described on the opposite page. Telescope is complete — no extras to buy. Look at all of these wonderful features. Erect image. Amici roof prism. Bends the light at 90° angle for comfortable viewing at zenith and also for terrestrial use. Three eyepieces supplied with the telescope: 6.0 mm. for high-power astronomical viewing, 12.5 mm. for medium power for viewing moon, planets, etc., and 28 mm. for low-power terrestrial and astronomical use. Small focusing eyepiece mount takes 1¼" outside diameter eyepieces. Contains built-in filters which can be changed by turning a small knob. Filters are red, yellow, neutral, and clear for use in planetary work.

The 8-power finder telescope has a real achromatic objective. Bends the image in a right angle for convenience in transferring your eye from the finder to the telescope. The heavy-duty equatorial mount can be adapted for all latitudes in astronomical viewing. It is quick and flexible for terrestrial use. Specially designed to adapt easily to slow-motion mechanism. Heavy-duty tripod adjustable for viewing at all heights. Overall length of telescope approximately 45". Shipping weight 100 lbs.

Stock #85,019-Y ..... **$195.00 f.o.b. Barrington, N. J.**

EDMUND SCIENTIFIC CORP.

3" ACHROMATIC TELESCOPE OBJECTIVE

Real Quality at an Unbelievable Low Price

MAKES A WONDERFUL 3" REFRACTOR

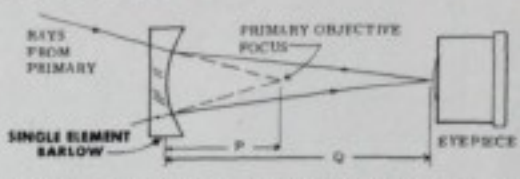
ONLY $28.00 ppd.

3-1/16" diam., 45" focal length. These were tested in the field by Hal Metzger, well-known amateur, and pronounced "equal to any 3" objective made anywhere today, even at two or three times the price". Letter is in our files. This is an air-spaced achromat. The air-spacing of a lens gives the lens designer four surfaces with which to correct aberrations, instead of only three surfaces, as with a cemented achromat. The result is a beautiful, color-free image, an image which is sharp, clear, with very flat field, no bad zones and fully corrected against coma. This objective is not coated, for we have reason to believe that after many cleanings a coated objective tends to scatter light and become inferior to a well-cleaned uncoated glass. This is your chance to build a 3" refractor at low cost. A refractor with a lens as good as this one would cost you about $400.00, if bought ready-made! We supply free with this lens a specially designed, spiral-wound laminated kraft board mount which is designed to slip over our 3" aluminum tube. This effectively solves your mounting problem.

STOCK #30,166-Y— 3" Achromatic Objective Color-corrected—air-spaced ..... $28.00 ppd.

Coming Soon! From the same manufacturing source. 2" x 50" f.l. and 4" x 60" air-spaced achromats! If you want information on these new objectives, write for Bulletin #30. We will send it when it is available.

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER with a BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power.

The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q!

ACHROMAT OR SIMPLE BARLOW? An achromatic Barlow lens will give best results, but our low-priced single-element lens will give you 90% of the performance of the achromat. In fact, on and around the axis, the image will be just as good, with slight additional color at the edges of the field.

SINGLE ELEMENT BARLOW—FOCAL LENGTH 1-5/16".

Unmounted, O.D. 1-3/16". Coated. Fits in tubing listed below.

Stock #30,175-Y ..... $3.00 ppd.

360° SETTING CIRCLE

Made of heavy black plastic material with white markings divided into 1 degree. Numbered every 10 degrees. Diameter 4". Hole diameter 2¼" with a ledge 3⅛". We also include, free of charge, the U.S. Air Force true air-speed computer, which is an instrument made of two disks of black plastic. Use with the setting circle if you make your own.

Stock #60,039-Y ..... $1.25 ppd.

BRASS TUBING

2 pieces, 3" long, slide fitting. Blackened brass. I.D. 1-3/16", O.D. 1-5/16". To fit single-element Barlow above. Complete directions.

Stock #40,165-Y ..... $1.25 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

One of our fine telescope mirrors, polished and aluminized, lenses for eyepieces and diagonal. No metal parts.

Stock #50,074-Y ..... $16.25 ppd.

7X — FINDER TELESCOPE — ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts $9.95

Stock #50,075-Y Ring mounts per pr., $4.95

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth.	Description	Price
80,038-Y	4⅛"	5¼"	46"	Spiral-wound paper	$2.50
85,008-Y	7"	7½"	60"	Spiral-wound paper	4.00
85,011-Y	2⅞"	3"	48"	Aluminum	6.00
85,012-Y	3⅝"	4"	60"	Aluminum	8.75
85,013-Y	4⅝"	5"	48"	Aluminum	9.00
85,014-Y	6⅝"	7"	60"	Aluminum	15.00

All tubing is shipped f.o.b. Barrington, N. J.

HUYGENS EYEPIECES

Here are some really terrific values in eyepieces! The three eyepieces listed below are manufactured by one of the world's best producers of optical components. We have searched the world's markets, including Germany and France, to find a real quality eyepiece. The image clarity, the workmanship evidenced in the metal parts, will prove the skill and experience of Goto Optical Company, Tokyo. Guaranteed terrific buys at these low prices!

HUYGENS TYPE — STANDARD 1¼" DIA.

6 mm (¼") Focal Length

STOCK #30,063-Y ..... $8.50 ppd.

12.5 mm (½") Focal Length

STOCK #30,064-Y ..... $8.00 ppd.

COMBINATION EYEPIECE

STOCK #30,065-Y ..... $9.00 ppd.

This Huygens eyepiece, used in different arrangements of the lens elements, gives focal lengths of 10 and 20 mm, allowing you to double the power of any objective or primary mirror. Standard equipment with our Palomar, Jr. reflecting telescope. Easy directions for assembling for different powers are included.

RACK & PINION EYEPIECE MOUNT

. . . Available with Diagonal Holder

Now—you can improve performance in a most important part of your telescope—the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these wonderful new features: Real rack and pinion focusing, with variable tension adjustment, gives you microscope-smooth focusing action. Focus travel over 2". Drawtube accommodates standard 1¼" eyepieces, giving your present telescope a wide, varied range of power. Standard size opening also allows the use of accessory equipment, such as sunspot projectors, filters, eyepiece prism diagonals and terrestrial erectors. Lightweight aluminum body casting. Rigid mounting achieved by drilling four small holes in tube, whether paper or metal. Drawtube and rack chrome plated brass, body in black wrinkle finish.

Stock #50,077-Y (less diagonal holder) 9.95 ppd.

Stock #60,035-Y (diagonal holder only) 1.00 ppd.

MOUNTED ERFLE EYEPIECE

68° FIELD OF VIEW

Consists of 3 coated achromats in metal mount with spiral focusing. F.L. 1¼". Dia. 54 mm., length 54 mm. War surplus. Govt. cost about $84.00. This is the type war surplus bargain that will be talked about in years to come. Buy while you can. Our price will jump soon.

Stock #5160-Y, 12.50 ppd.

WAR SURPLUS TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3, 2 achromats, F.L. 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for all types of telescopes. Govt. cost $26.50.

Stock #5223-Y, 5.95 ppd.

SPHERICAL TELESCOPE MIRRORS

Ground, polished, aluminized, silicon monoxide overcoated. You can't buy better quality. Remember, good Spherical Mirrors of f/10 and higher, are perfectly satisfactory for reflecting telescopes.

STOCK NO.	DIAM.	FOCAL LENGTH	PRICE
50,082-Y	3"	30"	$9.95
50,051-Y	4¼"	45"	15.00

RIGHT ANGLE PRISMS

Excellent for use as a diagonal on a Newtonian telescope. Also used in refractors to bend light rays for more comfortable viewing. These are all within ¼ wave length tolerance.

STOCK NO.	Dimension of Faces	Price ppd.
3252-Y	24 x 24 m.m.	$2.50
3155-Y	31 x 31 m.m.	3.00
3255-Y	38 x 35 m.m.	3.50
3169-Y	41 x 40 m.m.	3.00

BE SURE TO GET FREE CATALOG "Y" Fantastic variety — never before have so many lenses, prisms, optical instruments, and components been offered from one source. Positively the greatest assembly of bargains in all America. Imported! War Surplus! Hundreds of other hard-to-get optical items. Write for *Free Catalog "Y"*.

LATEST MODEL SPITZ Jr. PLANETARIUM

Designed by Armand Spitz. Projects nearly 400 stars, more than 70 constellations in their correct relationships. Use it in any darkened room of the house, project it on walls and ceiling. No batteries, works on ordinary household current. Two simple adjustments that show you the sky as it appears from any point in the Northern Hemisphere . . . for any time of night . . . for any month of the year! Rheostat brightness control. A 32-page book included free of extra cost. Contains valuable information about the stars, provides easy identification of the constellations. Also FREE — illuminated pointer.

About 14" high on a 7" x 7" base. Projection sphere 7" diameter. Weight 3 lbs. Now available supplementary spheres for Southern Hemisphere and "Sky Zoo."

Stock #70,040-Y ..... $14.95 ppd.

MISCELLANEOUS ITEMS

MOUNTED BARLOW LENS — Short Focal Length. E.F.L.: −1.74±0.01 inches. Clear aperture: 0.96" O.D. of cell: 1⅛".

Stock #30,140-Y ..... 15.00 ppd.

STAR SPECTROSCOPE — Imported! Doubles the usefulness of your Telescope. 2¾" long.

Stock #50,023-Y ..... 32.75 ppd.

60° SPECTROMETER PRISM — Polished surfaces 18 mm x 30 mm — flat to ½ wave length.

Stock #30,143-Y ..... 8.25 ppd.

ORDER BY STOCK NUMBER . . . SEND CHECK OR MONEY ORDER . . . SATISFACTION GUARANTEED!

BARRINGTON • NEW JERSEY

STAR FINDER TELESCOPE

Uses a very fine objective and eyepiece. No crosshair. High eye relief. 6 power. Weight 2 lbs., 10 oz. Diameter 2¼" x 12" long. Complete with optics. **$30.00 plus postage**

FINDER BRACKETS

Brass rings 2⅜" inside, with three centering set screws set in circumference, have feet attached which can be secured to outside of telescope tube. Per set of 2 **$5.00**

PRECISE FOCUSING MECHANISM

For Reflectors or Refractors

Takes Standard 1¼" Eyepiece

Full 1¼" of fine focusing motion with 3" of extension tube. One revolution of knurled knob produces 0.163" motion along optical axis. Absolute centering guaranteed. No play. Will not bind or lock. No rack-and-pinion to strip. Precision manufacture allows smooth, easy positive focusing. Adapted to every type of telescope construction. Drilled to hold diagonal mirror support. Of brass throughout. Weight 1 lb. **$18.50**

ACHROMATIC NEGATIVE BARLOW LENS

Read what Mr. R. A. Gibson of Nutley, N. J., says:

"You may be interested in knowing of the excellent results I am obtaining with the Negative (Barlow) Achromatic lens.

"I have a 6" telescope using one of your (Ross) mirrors. I get a magnification of 300x using a ¼" eyepiece. With this combination I get excellent resolving power. By adding the Barlow lens to the ¼" eyepiece, I obtain a magnification of 450x with equally good resolving power."

Magnification factor 1½ times. Little loss of light. Minimum astigmatic distortion. Achromatic negative lens in aluminum mount; 1-1/16" diameter; minus 12" f.l. Outside surfaces fluoride coated. **$2.00 each**

STAR DIAGONAL

For the convenient observation of stars near the zenith, a prism is indispensable. It is placed before the eyepiece to direct the pencil of light rays so that the axis of the eye-lens is at right angles to the axis of the telescope. Our "Star Diagonal" is especially manufactured for this purpose. Fits standard 1¼" eyepiece holder and takes standard 1¼" eyepieces. Price, including fine quality light flint glass fluoride coated 1⅝" prism: **$15.50**

Equivalent straight-tube length 4".
Prism easily removed for cleaning.

SAFETY SUN FILTERS

The SAFE AND SANE way to look at the SUN—use our Special Safety Sun Filters. Each one is 50-mm. (2") diameter and 2-mm. (1/16") thick; polished flat on both sides.

1. View the sun **directly** by looking through filter with unaided eyes.
2. Place filter at the **eyepoint** of the ocular and observe with any power after limiting the objective (with a diaphragm) to under 2".
3. Use filter as a limiting diaphragm in front of the objective of the telescope.

For Winter sunlight use #WF12
For Summer sunlight use #SF14

Only $2.00 each or **$3.00 per set** of any 2 above.
Remit with order. Include postage. No C.O.D.

HARRY ROSS

Telescopes - Microscopes

Comprehensive Catalog — $1.00

70 West Broadway, New York 7, N. Y.

GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

An Electric Portable Reflector

AS AN INSTRUCTOR in the telescope making classes conducted by the Optical Division, Amateur Astronomers Association, I have made the 6-inch f/8 reflector illustrated here. The Optical Division conducts classes in mirror processing and has a fine machine shop in the basement of the Hayden Planetarium in New York City.

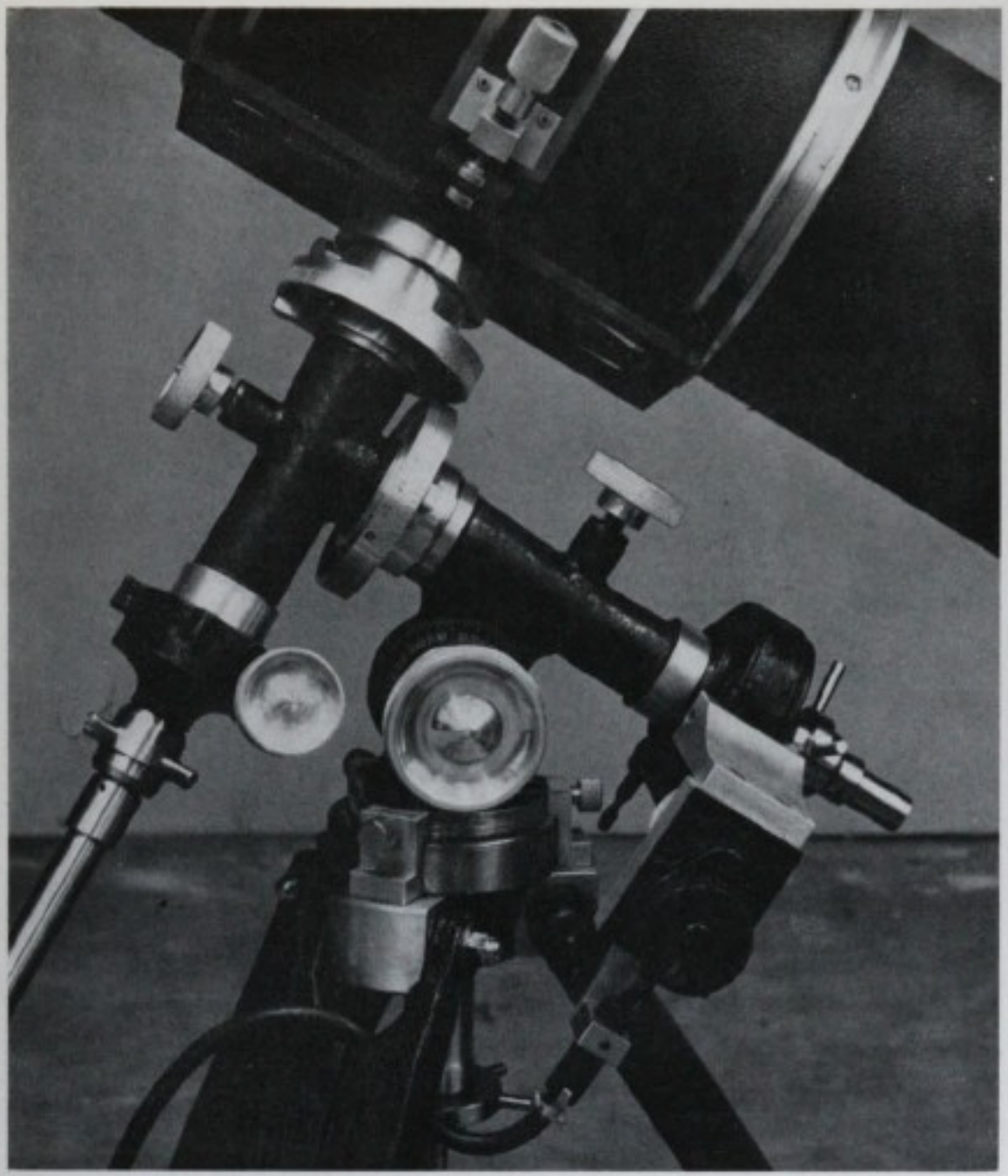
The metal parts of the instrument are machined from aluminum castings and stainless steel. The 52" tube is of bakelite, covered with black imitation-leather cloth such as is used on cameras. There are two finders, the larger giving 6 power and an erect image, as it has a roof prism. The smaller one was made from the 2x eyepiece of a war-surplus sextant.

Also at the eye end of the telescope are a long bar that serves as a counterweight, and an aluminum ring to give better support for the spider that holds the diagonal flat and secondary assembly inside the tube.

The mirror cell can be removed and reinserted into the aluminum ring at the lower end of the tube without disturbing the collimation of the optical system. At the middle of the tube is a strap and snap-clamp arrangement which allows instant removal of the telescope tube from its saddle. The tube can be rotated by any amount necessary to bring the eyepiece into a convenient position.

The setting circles can be turned by hand to any position, yet there are no set screws needed to keep them moving with the declination and polar-axis shafts. The index posts can be similarly adjusted, without set screws.

Maurice Shapiro's 6-inch reflector has an electric drive.



This closeup shows details of the equatorial head.

The manual declination control and the right-ascension drive utilize worm gears salvaged from war-surplus panoramic sights. A small electric clock that I made from war-surplus parts drives the instrument. The telescope can be moved by hand while the drive is running, but there are clutches attached to each slow motion for quick disengaging if necessary.

At the top of the tripod head, I inserted a large ball bearing and race from the rear end of a junked car. This permits easy rotation of the telescope in a horizontal plane for terrestrial use; the roof prism in the star-diagonal eyepiece holder provides an erect image.

The tripod itself is of aluminum. It is braced by an umbrella arrangement of aluminum bars, and the vertical shaft of stainless steel allows the tripod to be easily collapsed for portability. My eyepieces were all machined from aluminum, and surplus lenses were used for most of them. This instrument has well repaid my efforts in building it. I will be glad to answer questions about its construction.

MAURICE SHAPIRO
40 E. 169th St.
New York 52, N. Y.

HOW MUCH DOES TEMPERATURE RISE DURING POLISHING?

BOOKS on telescope making discuss the changes in temperature of mirror and tool during the polishing and figuring stages. While polishing a 6-inch f/3.5 mirror, I performed an experiment to determine just how much temperature change was involved.

A Chromel-Alumel thermocouple junc-

ASTRONOMICAL INSTRUMENTS
OF QUALITY
Made in America
Optical Instruments including standard Telescopes and all accessories.
Ramsden eyepieces from ¼" to 1½" focal length **$9.50**
Kellner eyepieces from ¼" to 1" focal length **$15** to **$18**
Orthoscopic eyepieces in 1/3", 2/3", and 1" focal length **$20**
SPECIAL!
6" Equatorial refractor, pier-mounted, electrically controlled and actuated motions **$1,800**
LABORATORY OPTICAL CO.
Plainfield, New Jersey

ALUMINIZING
ALUMINUM OVERCOATED
CHROMIUM ALLOY
★★★ **BERAL COATINGS** ★★★
The ideal coating for front surface **precision** mirrors for these reasons:
1. Beral has HIGH reflectivity.
2. Beral is HARD; does not sleek easily.
3. Beral can be cleaned easily — no porous OVERCOATING of quartz.
4. Beral is NOT a Chromium alloy, so can be removed easily.

Prices for Beral coating telescope mirrors: 3"-$2.25, 4"-$2.75, 5"-$3.00, 6"-$3.50, 7"-$4.00, 8"-$4.50, 9"-$5.50, 10"-$6.50, 11"-$8.50, 12½"-$9.75. Prices for sizes up to 37" diameter on request. Add Postage — Insurance for return shipment.
LEROY M. E. CLAUSING
8038 MONTICELLO AVE. SKOKIE, ILL.

Complete Telescopes
6" as illustrated $660

Supplies
Ramsden Eyepieces $6.15 postpaid
Eyepiece and Prism Holders
Mirror Cells
Finders
Equatorial Mountings $100 up
Prisms
Write for price list
C. C. YOUNG CO.
25 Richard Road, East Hartford 8, Conn.

Aluminized Pyrex
Parabolic Telescope Mirrors

Diameter	*Specification (mercury light)*		
	¼ wave	*⅛ wave*	*1/15-1/20 wave*
4¼"	$30.00	$40.00	$300.00
6"	50.00	65.00	450.00
8"	65.00	85.00	675.00
10"	115.00	145.00	1000.00
12½"	195.00	250.00	2100.00

Revised price list

The mirrors in the last column are guaranteed to be within the tolerances stated and are free of astigmatism. Edge has ⅛" ground from diameter for manufacturing expedient. Delivery by written appointment.
NYE OPTICAL COMPANY
2100 Cherry Avenue Long Beach 6, Calif.

Astronomical Supplies

ORTHOSCOPIC OCULARS

All hard coated

28 mm. $13.00 — 7 mm. $15.50
16.8 mm. $13.50 — 4 mm. $16.50
10.5 mm. $14.75

Warranted to equal or surpass any oculars obtainable anywhere or money refunded.

Mirrors, kits, castings, spiders, flats, focusing devices, prisms, aluminizing.

Send for Catalogue.

Telescopics

1000 N. Seward St., Los Angeles 38, Calif.

DELUXE PYREX

Reflecting Telescope Kits

Our kits have PYREX mirror blank, PYREX tool the same thickness, ample supply of optical quality abrasives, fast polishing cerium oxide, red rouge and pitch. Packed in metal cans.

Size	*Thickness*	*Price*
4¼"	¾"	$ 5.50
6"	1"	$ 9.50
8"	1½"	$17.00
10"	1¾"	$29.95
12½"	2⅛"	$52.95

ADD POSTAGE: 1st and 2nd postal zones from Detroit, add 5%; 3rd and 4th, add 10%; 5th and 6th, add 15%; 7th and 8th, add 20%. Or we will ship C.O.D.

ASHDOWNE BROS.

18450 Grand River — Detroit 23, Michigan

TELESCOPE MAKING SUPPLIES

4-leg Spider or Diagonal Holder, made of brass, with threaded steel rod. **$1.50**

Eyepiece Holder, brass tube in pressed steel flange. Fits standard eyepiece. **$2.50**

Long Focus Ramsden Eyepiece. 2 polished plano-convex lenses mounted in plastic tube. Standard 1¼" O.D. 30-mm. e.f.l. **$2.00**

PYREX MIRROR MAKING KITS

Consist of PYREX mirror blank with either plate glass or additional Pyrex for tool. **Six** selected abrasives, pitch, rouge, and cerium oxide.

Diameter	Plate-Glass Tool	Pyrex Tool
6"	$ 8.75	$ 9.75
8"	$11.75	$16.50
10"	$20.00	$29.00
12½"	$36.75	$51.00

Postage Paid to 1st and 2nd postal zones from N. Y. Add 5% 3rd and 4th zones, 10% 5th and 6th zones. Add 15% 7th and 8th zones.

Send for free catalog of optical supplies.

DAVID WILLIAM WOLF

74 Hunnewell Ave. — Elmont, L. I., N. Y.

tion was buried near the center of the pitch lap, about 1/16" below the surface. Thermocouple wires were brought out to the periphery of the tool along the bottom of one of the V grooves in the tool. These were connected to a Leeds and Northrup galvanometer, for which a change of 0.041 millivolt corresponds to a change of one degree centigrade at the thermocouple. A thermometer suspended directly above the polishing table showed no more than half a degree Fahrenheit variation in air temperature during the experiment. The reference junction of the thermocouple was in a mixture of distilled water and ice made from the water.

Since I never use a handle on a mirror, a pair of heavy leather gloves was worn to minimize transfer of heat from my hands to the work. Two-inch strokes were used at a rate of about 100 per minute, with rouge as the polishing agent.

The experiment was in three parts. In the first, I polished for 15 minutes, during which the temperature rose 3.9° C. A slight increase in temperature was observed after the actual polishing had stopped, indicating that the tool had variations in temperature. The mirror was left on the tool, and it took more than three quarters of an hour to return to the original temperature.

In the second case, the polishing action of 15 minutes brought the reading up again to a slightly higher value than before. The mirror was then taken off the tool, which cooled to its original temperature in about 10 minutes. Probably this was true only for the exposed upper surface; the lower portions may well have taken longer to cool.

For the third part, I tried an unusually long period of polishing, 27 minutes, which raised the temperature 5.85° C. The mirror was again left on the tool, and this time it took almost an hour to return to the original temperature.

The following data for the first case indicates how the cooling took place: Polishing began with a reading of 0.70 mv. at 10:10 p.m.; polishing ended, 0.86 mv., at 10:25. During cooling the readings were 0.87 at 10:27; 0.80, 10:37; 0.75, 10:50; 0.73, 11:00; 0.71, 11:15.

For a 6-inch f/8 mirror the depth of glass removed in figuring is about 11 millionths of an inch. At a temperature increase of 4° C., the expansion exceeds this amount, since with a coefficient of expansion of 3.3×10^6 per degree centigrade, we get 4×3.3 or 13.2 millionths.

These results indicate that the optician's habit of polishing for short periods and waiting for the mirror to cool before testing is indeed the correct procedure. After any lengthy polishing spell, at least an hour's time should be allowed for cooling before knife-edge tests are attempted.

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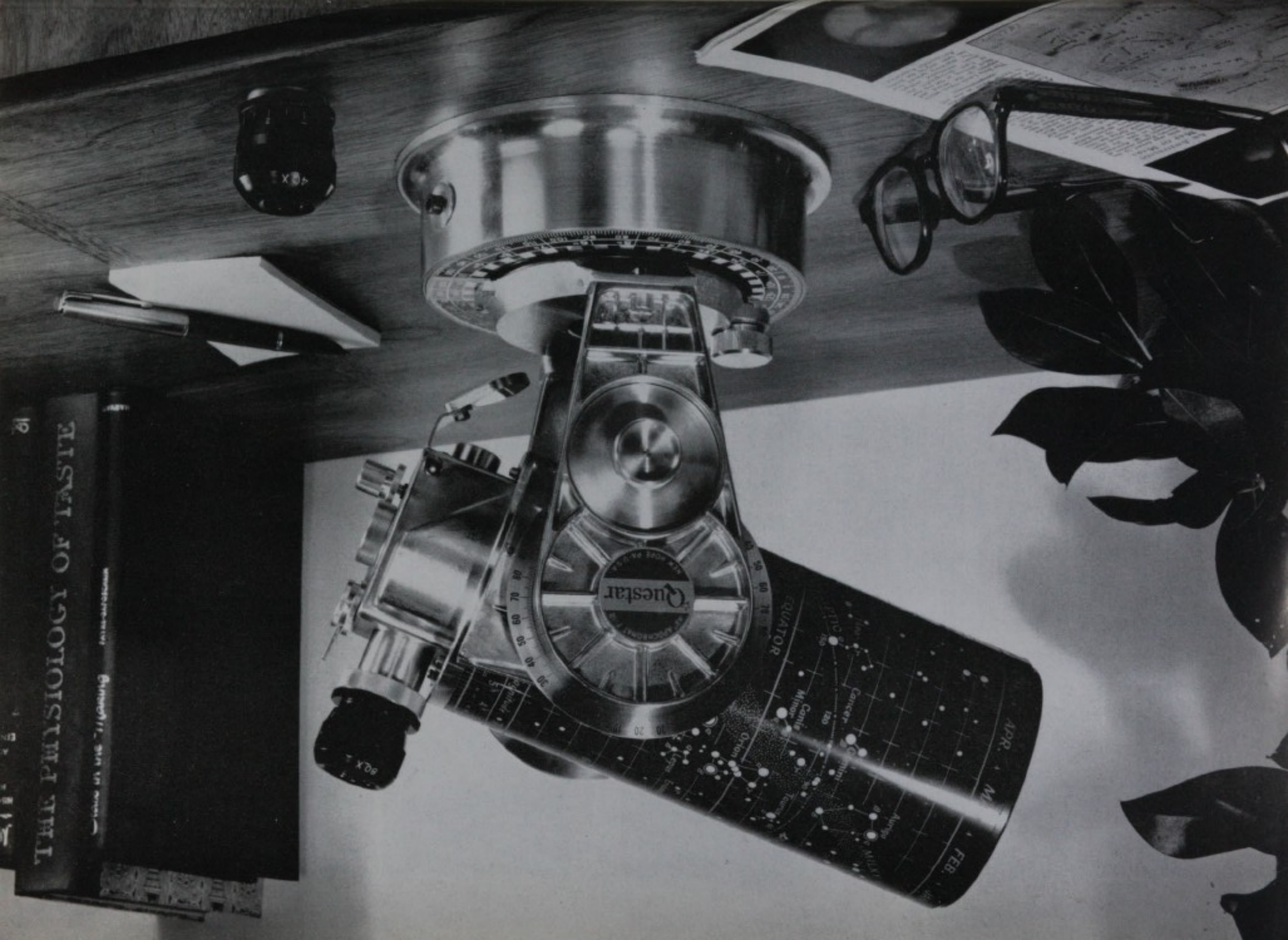
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Astronomical telescopes, like research microscopes, are set apart from ordinary optical devices, in that each must be able to show as much fine detail as the best lens or mirror of like diameter that man can polish.

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Conventional long-tubed instruments are difficult enough to produce, but consider for a moment the problem of severely shortening a telescope's overall length. Consider in fact just one of the problems that had to be solved before Questar could offer all the benefits of convenience and portability possible to a telescope with a very short tube. It appears to be about four times harder to make an f/4 mirror than an f/8, while f/2 mirrors like Questar's must be something like sixteen times more exquisite of surface to withstand our requirements that they act as though their focal length

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Epsilon Aurigae Begins Two-year Eclipse

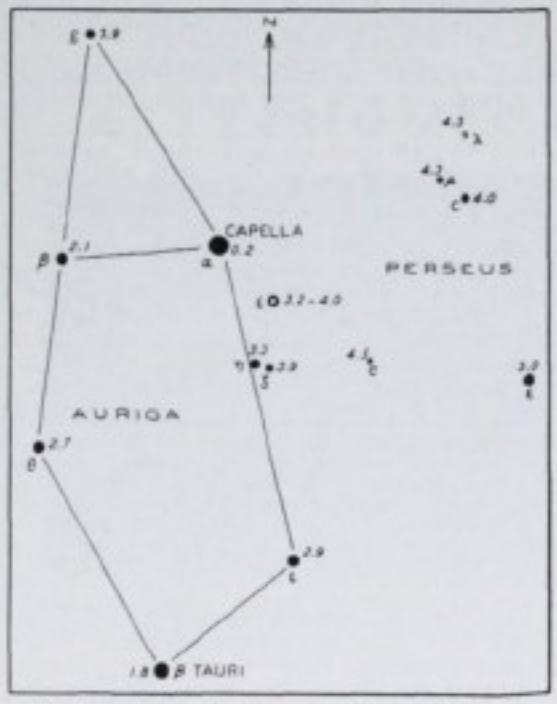
DURING the next two years, Epsilon Aurigae will be one of the most talked-of stars among astronomers. It will undergo a two-year eclipse that can be watched by any amateur, using no equipment except the naked eye. This star is located at the apex of the small triangle of stars known as the Kids, near Capella, located low in the northwest after sunset this month.

The sequence of events opens with the beginning of eclipse this June. Epsilon Aurigae, normally of magnitude 3.2, will fade very gradually until it is 0.8 magnitude fainter by December, 1955. The variable will then remain at minimum light until November, 1956, when a slow recovery will set in, bringing the star back to full normal brightness in May, 1957. Superimposed on this pattern of light changes are small, irregular fluctuations ranging up to 0.2 magnitude.

Epsilon Aurigae is an eclipsing binary star with the exceptionally long period of 27.1 years. Its brighter, *F*-type component will undergo photometric eclipse, but already spectral changes associated with the eclipse have been observed, as described in the article by Otto Struve in the February, 1953, issue. There the beginning of the 1955 eclipse was erroneously given as August, instead of June.

This double star system is one of the outstanding puzzles in astronomy today. The star that is being eclipsed is a supergiant, probably about 300 times the diameter of the sun, as large as Antares. The eclipsing component is believed to be 1,000 times larger yet, in volume, and is so tenuous that the *F*-type star continues to shine through it even though the eclipse is "total." However, Z. Kopal has suggested instead that the eclipses are caused by a flat ring of solid particles surrounding the invisible companion (*Sky and Telescope*, November, 1953, page 6). In this case, the invisible star would probably be much smaller, but the ring would be not much less in extent than our solar system.

The accompanying chart of the brighter stars in Auriga and vicinity gives their visual magnitudes, taken from the Harvard Revised Photometry. Epsilon Aurigae, marked with a circle, is at maximum light slightly brighter than Eta, and at minimum somewhat fainter than Zeta. These two neighboring stars will be useful standards of comparison for visual observers of the light changes of Epsilon.



Epsilon (ε) Aurigae and neighboring stars in the Auriga-Perseus region.

MOON PHASES AND DISTANCE

Full moon	June 5, 14:08
Last quarter	June 13, 12:37
New moon	June 20, 04:12
First quarter	June 27, 01:44
Full moon	July 5, 05:28

	June	Distance	Diameter
Apogee	5, 03h	252,400 mi.	29′ 25″
Perigee	19, 14h	222,400 mi.	33′ 23″
	July		
Apogee	2, 09h	252,200 mi.	29′ 27″

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CORRECTION

On page 267 of the May issue, the first three lines of the second paragraph of the article "A 60-foot Radio Telescope for Harvard Observatory" should read: "The radio astronomy project at Harvard is directed by Prof. Bart J. Bok, who is R. W. Willson professor of applied astronomy, and Dr. Ewen."—ED.

MARS OCCULTATION

Although the April 24th occultation of Mars by the moon was not listed for station **F** (longitude 98°.0 west, latitude 31°.0 north), some 130 miles south of here, a grazing occultation occurred at Dallas. Ted Cramer and I watched Mars disappear at the southern tip of the crescent moon at 9:07 p.m. CST. Emersion was timed at 9:30. Ted Gangl, two or three miles west of us, also saw the immersion. All three observers are members of the Texas Astronomical Society.

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At 8:15 p.m. (Pacific daylight time), Mars was too close to the moon to be seen, even in a 16x hand telescope. By 8:30, the moon had moved 3′ away from the planet, and by 8:55 their separation was about 11′. They were in a patch of clear sky until 9:05, when Mars became very hard to see.

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VARIABLE STAR MAXIMA

June 5, V Bootis, 142539a, 7.9; 9, R Sagittarii, 191019, 7.2; 15, T Centauri, 133633, 6.1; 16, U Cygni, 201647, 7.6; 18, R Indi, 222867, 8.0; 22, RT Cygni, 194048, 7.4; 23, S Coronae Borealis, 151731, 7.5; 24, RS Herculis, 171723, 8.0; 26, S Virginis, 132706, 7.1. July 4, T Aquarii, 204405, 7.9; 7, R Reticuli, 043263, 7.7.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

SUNSPOT NUMBERS

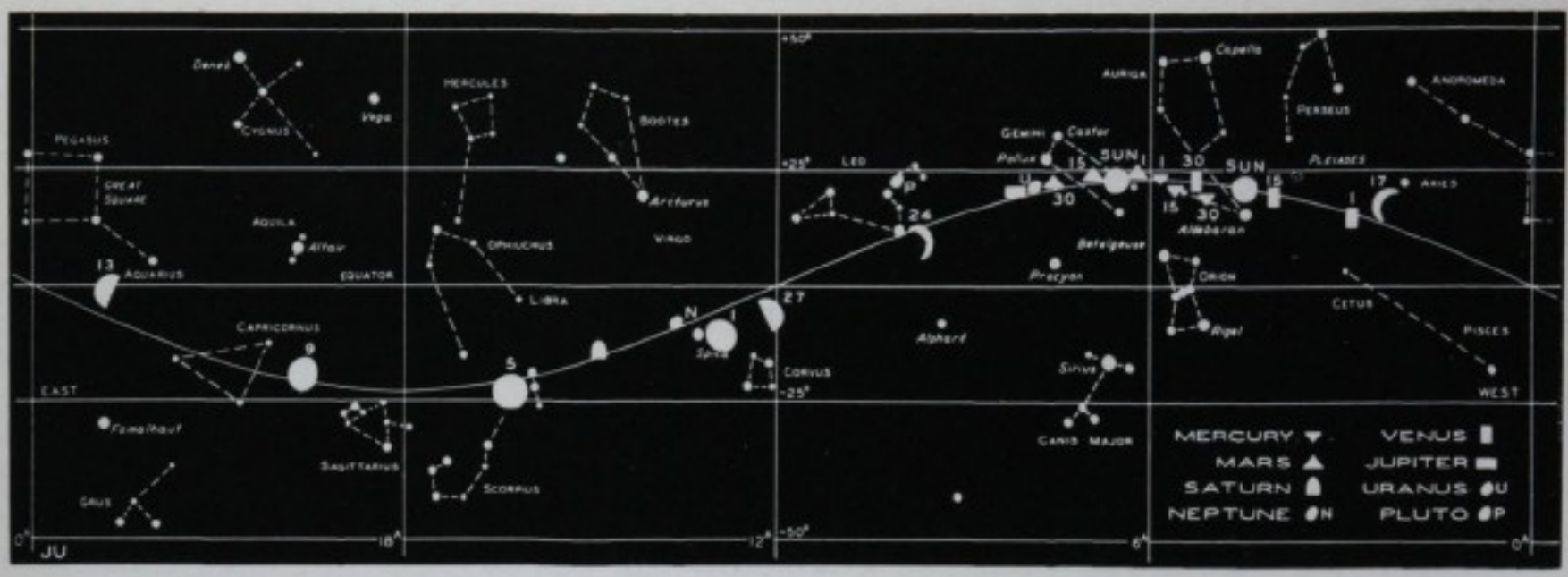
March 1, 29, 23; **2**, 22, 20; **3**, 19, 16; **4**, 14, 15; **5-6**, 10, 8; **7-8**, 3, 8; **9**, 2, 7; **10-20**, 0, 0; **21**, 2, 0; **22-26**, 0, 0; **27**, 2, 7; **28**, 0, 0; **29**, 6, 0; **30**, 13, 17; **31**, 12, 10. Means for March: 4.7 American; 4.7 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

At the U. S. Naval Observatory, the daily sunspot observations include the measurement, from photographs, of the total area of the visible spots. These areas, which include both umbra and penumbra of each spot, are expressed in millionths of the area of the visible hemisphere. *Circular* 57 of the Naval Observatory lists the spot areas for each day of 1954; the average for the year was 44, and the monthly means ranged from 182 in March to 0 in January and June.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

The sun will undergo a total eclipse of long duration on June 20th, visible from southern Asia and the southwest Pacific. For maps and other information, see the February issue, page 142, and May, page 279.

Mercury cannot be seen easily during June, because inferior conjunction with the sun occurs on the 16th. The planet will also be fainter than usual all month.

Venus is now hard to see, rising about one hour before the sun throughout the month. Its disk, 10".7 in diameter, is 93 per cent illuminated on the 15th.

Earth arrives at heliocentric longitude 270° on June 22nd at 4:32 UT, when summer begins in the Northern Hemisphere and winter in the Southern.

Mars becomes lost in the evening twilight at the beginning of June and will not be seen again till October, in the morning sky.

Jupiter can be found low in the western sky after evening twilight ends, setting about 2½ hours after the sun on the 15th. Now an object of magnitude −1.4, the planet is moving eastward in Cancer. Its equatorial diameter is 32".5 in mid-June.

Saturn and Neptune are the only planets in the midnight sky. The ringed planet may be observed until dawn in midmonth, in retrograde (westward) motion in Libra. On the 15th, Saturn will shine at magnitude +0.5. The rings will be inclined 20°.8 to our view.

Uranus may be viewed with slight optical aid during the first days of June, low in the west after sunset. This 6th-magnitude planet is moving eastward near the Gemini-Cancer boundary line.

Neptune will be visible till after midnight all month, appearing at 8th magnitude. It is in slow retrograde motion between 81 and 82 Virginis, about 4° northeast of Spica. E. O.

MINIMA OF ALGOL

June 3, 7:10; 6, 3:59; 9, 0:48; 11, 21:36; 14, 18:25; 17, 15:14; 20, 12:02; 23, 8:51; 26, 5:40; 29, 2:29. July 1, 23:18; 4, 20:06; 7, 16:54; 10, 13:43.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

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The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 7th and 23rd of August; also, at 9 p.m. and 8 p.m. on September 7th and 23rd. For other dates, add or subtract ½ hour per week. When facing south, hold "South" at the bottom; turn the chart correspondingly for other directions. Celestial hour circles and parallels are represented as parts of circles, and an observer's horizon is always a circle on the stereographic projection used in these charts.

STARS FOR JUNE

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of June, respectively; also, at 7 p.m. on July 7th. For other dates, add or subtract ½ hour per week.

High on the meridian, yellow-orange Arcturus is readily found. Note its color contrast with the cold white of Spica, lower and farther west in the sky. In the northern sky, Ursa Minor is well placed, as the Little Dipper stands on its handle-end, Polaris.

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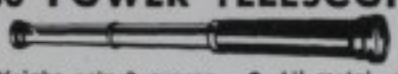

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(Continued from page 334)

prominent professional astronomer in a leading scientific journal, together with full details and a complete orbit computation. The man was F. Petit (1810-1865), director of the Toulouse Observatory, whose communication to the French Academy of Sciences was printed in its *Comptes Rendus* of October 12, 1846.

Three observers saw the body, Lebon and Dassier at Toulouse, and Larivière at Artenac, 26 miles away, on March 21st of that year, at 6:45 p.m. When Larivière first noted this luminous object, it was low in the south, near Sirius; it moved slowly past Orion and into the northwestern sky, where it vanished behind a low cloud bank. It stayed in sight for 10 seconds, and its apparent diameter was half that of the moon.

First supposing this object to be a meteor, Petit calculated its track, and found to his surprise that the observations indicated an elliptical orbit around the earth with a period of revolution of 2 hours 44 minutes and 59 seconds. The mean distance from the center of the earth came out 6,180.1 miles, and the orbital eccentricity 0.36007. Therefore, at perigee—the time of observation—the body would have missed the earth's surface by only 7.1 miles. Why this conspicuous object was not earlier recognized was easily explained by Petit: At less favorable apparitions its much greater distance from earth would make it correspondingly fainter.

In the audience at the French Academy when this paper was read sat the great Leverrier, codiscoverer of Neptune. He commented that the orbit calculation should be revised to take air resistance into account.

Hindsight is easy, when an additional century of experience by meteor astronomers is available to us. In 1846 the calculation of meteor heights and paths was still a novelty, and Petit had not realized that the observations were too rough to support such an elaborate superstructure of computation. His orbit depends very critically upon the uncertain estimates of the duration of visibility. The 10-second duration reported by Larivière leads to an elliptic orbit that intersects the earth's surface twice; the six seconds of the Toulouse observers makes the orbit around the earth a hyperbola. Petit had arbitrarily averaged these durations for his calculations with seven-place logarithms!

Petit's similar discovery of a second supposed earth satellite on July 23, 1846, also appears invalid, from uncertainty in the all-important estimates of duration. There can now be hardly any doubt that both these objects were merely ordinary fireballs. Clyde Tombaugh need not fear having been anticipated 109 years ago, if he finds a satellite of the earth.

J. A.

Wind Instruments

Wind Speed Indicator No. 410 Three-cup anemometer is mounted out-of-doors and registers speed of wind directly in miles per hour on an indoor indicator. The 4-inch polished brass dial shows speeds up to 100 miles per hour. Spinning cups generate a small current which is measured on the voltmeter indicator. No external power source is required. Anemometer is connected by low voltage, two-conductor No. 22 wire. Diameter of cup rotor is 10 inches. Height of pipe support is 12 inches. (Will operate at distances over 50 feet to about 200 feet if No. 18 two-conductor, copper, outdoor telephone wire is employed; this should be procured locally.) Complete, ready for installation and operation, with 50 feet of wire and pipe support. Shipping weight 4 lbs. **$49.95**

Wind Direction Indicator No. 411 A small wind vane is mounted out-of-doors and transmits wind direction to eight compass points on an indoor indicator. The vane has eight built-in contacts which complete an electrical circuit to the indicator. The vane assembly, which requires no maintenance, has a nine-conductor cable attached, the other end being connected to the eight lamps of the indicator. The proper lamp flashes on the indicator for the direction from which the wind is coming at that moment. Dial is 7½ inches in diameter by ¾ inch deep. The dial is plugged into regular 110-volt a.c. house current. Consumes only 1/25th of a watt. Outdoor transmitter height is 12 inches. Cable diameter ¼ inch. Shipping weight 4 lbs. Complete with 50 feet of cable. (Additional cable, $7.50 per coil of 50 feet.) **$49.95**

Compass No. 491 Enables one to tell the direction of the wind when out-of-doors. Rugged 2-inch maroon plastic case with hinged cover. Jeweled center. Sensitive bar needle locks automatically when case is closed. **$2.75**

Design Weather Vanes No. 431 These attractive wind vanes are both practical weather instruments and ornamental assets for your house or garage. Many designs in stock; send for complete folder.

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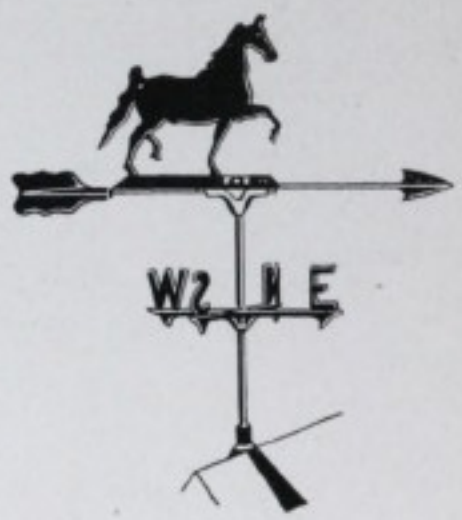

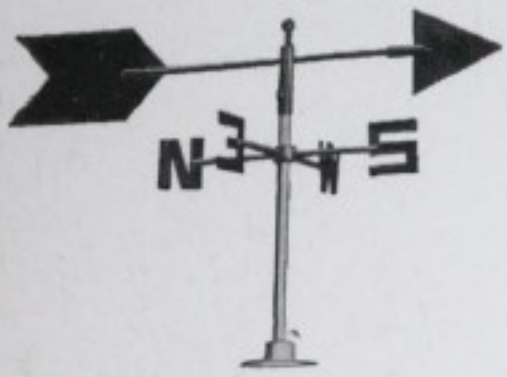

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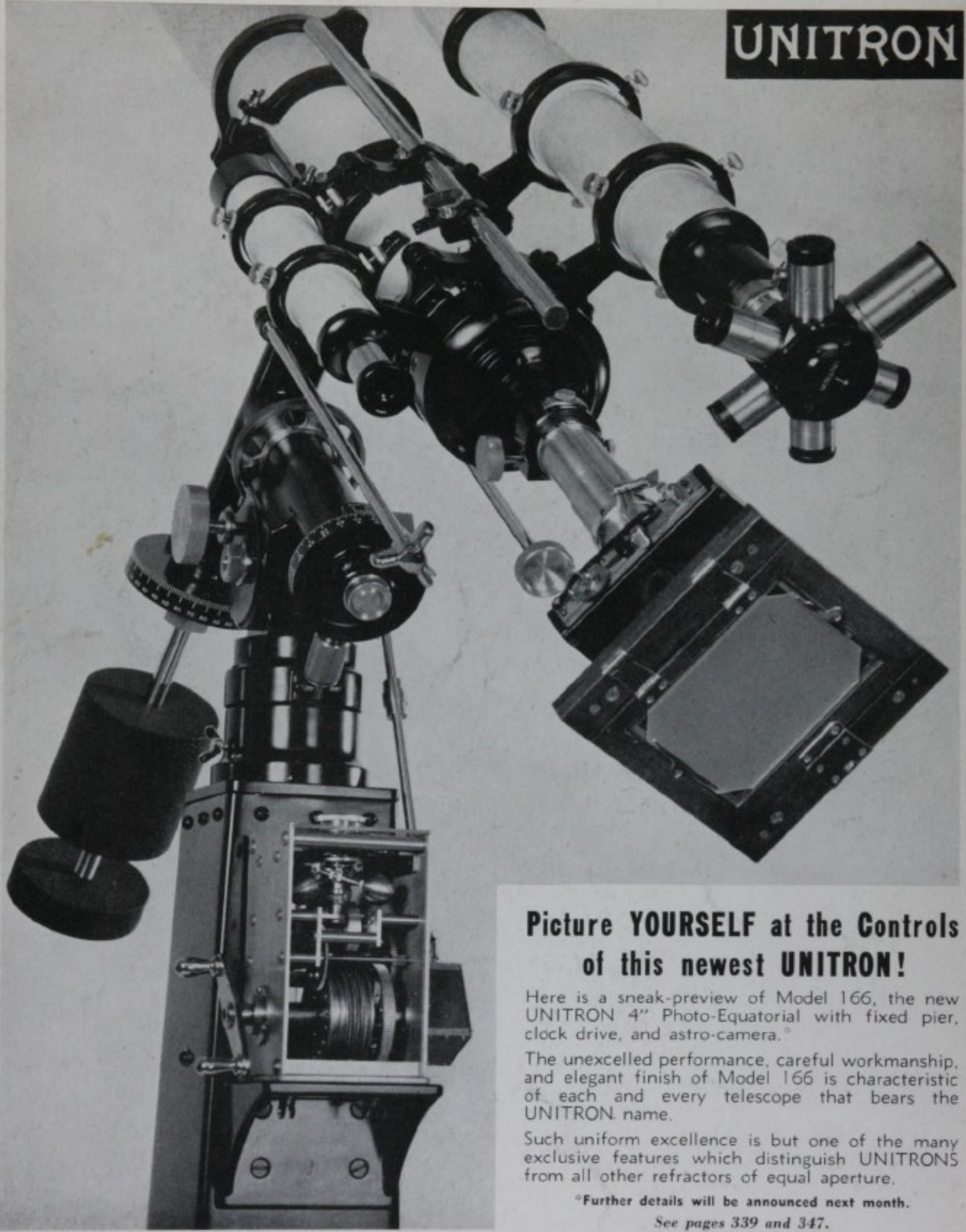

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***Further details will be announced next month.**

See pages 339 and 347.

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